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(NASA-CR-148740) AN AUTOMATED SYSTEM FOR CHROMOSOME ANALYSIS. VOLUME 2: SYSTEM CONSTRUCTION, PROGRAMMING, OPERATION, AND MAINTENANCE Final Report (Jet Propulsion Lab.) 228 p HC $8.00 CSCL 06B G3/51

N76-30786

Unclas 50272

JET PROPULSION LABORATORY

CALIFORNIA INSTITUTE OF TECHNOLOGY

PASADENA, CALIFORNIA

AN AUTOMATED SYSTEM FOR CHROMOSOME ANALYSIS

VOL. II. SYSTEM CONSTRUCTION, PROGRAMMING, OPERATION, AND MAINTENANCE

(FINAL REPORT)

1200-240 June 30, 1975

Prepared for the

National Institute of Child Health

and Human Development

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FOREWORD

This is the final report on NIH/NASA Interagency Agreement No. 1-Y01-HD-30001-00, a Contract Program to produce an Automated System for Chromosome Analysis. This report covers the period February 1, 1973 through April 30, 1975. It is supplied to the National Institute of Child Health and Human Development (NICHD) as required under the agreement.

This report is produced in two volumes for convenience of distribution. Volume I describes the goals of the program and the system design and performance. Volume II details the construction, programming, operation and maintenance of the system; it should be required only by persons wishing to operate, maintain or modify the system or to duplicate it in whole or in part. Distribution of volume II is controlled by the Project Officer at NICHD. This two-volume report provides complete technical documentation of all work performed under the interagency agreement.

A portion of the work, the development of a semi-automated specimen preparation unit and coordination of the karyotyping test program, was performed at the City of Hope National Medical Center in Duarte, California, under subcontract from JPL.

This report contains contributions from and reflects the dedicated efforts of Howard Frieden, Joe Fulton, Larry Goforth, Sayuri Harami, Greg Jirak, Elbert Johnson, Arnold Kochman, Shirley Quan, Gary Persinger, Linda Ravene, Paul Rennie, Ray Wall, and Gary Yagi.

CONTENTS

CONTENTS (contd)

SECTION I

INTRODUCTION

This is Volume II of the final report on an automated system for chromosome analysis, NIH/NASA Interagency agreement No. 1-Y01-HD-30001-00. It contains information relating to the operation, programming, construction and maintenance of the system. Volume II is intended for persons who wish to use the system produced under the interagency agreement, to construct a similar unit, in whole or in part, or to utilize software developed under the program.

Volume II is not independent of Volume I in that little of the material is duplicated. Therefore, frequent reference to Volume I, as well as certain manufacturers documents, may be required. Because of their bulk and their small audience, certain drawings, wire lists, and computer program listings are omitted. Copies of this material will be made available to appropriate persons by JPL upon request of the NIH Project Officer for this contract.

Volume II contains an operator's manual, computer program documentation, hardware construction details, and a maintenance manual.

SECTION II

OPERATOR'S MANUAL

A. SYSTEM OPERATION

1. General Keyboard Information

a) All input must end with a carriage return (CR key).
b) Answer all questions with a Y (and CR) for yes, or CR for no.
c) "RUB OUT" key erases the last character.
d) CTRL plus U erases the entire line.
e) CTRL plus C allows a monitor command (such as KI to kill the program).
f) When search start is pressed, the following messages will appear.
g) "ENTER PATIENT ID" - type up to 10 characters of patient ID.
h) If you wish to abort the search, type "A".
i) To use the same ID as before, type CR (carriage return).
j) "ENTER PATIENT SEX" - type M for male, F for female, U or CR for unknown.
k) "ENTER SLIDE ID" - type up to 8 characters of slide ID.
l) "ENTER SOURCE CODE (NEGATIVE FOR BANDED)" - normally type 1 or -1.

2. Power Up Procedure

a) Put enable/halt switch on halt (if not already there).
b) Turn key to power position.
c) Push run/load key on all 3 disks to run
d) Turn on Hughes memory, Conrac monitors, hardcopy, and microscope.
e) Set 773110 in switches and press load address.
f) When disk is ready, move enable/halt switch to enable and press start
g) Enter date as DD-MMM-YY and time as HH:MM.
h) Type CR in response to "DIALOGUE?".
i) Type LO 2,2 in response to "$".
j) Type "R CALMS".
The decwriter types "Is this a restart". If it is not a restart, type carriage return.

k) Lower the stage and condenser and hit the keyboard request button to initiate calibration of the microscope. The decwriter will type "ENTER REQUEST".

l) Type "C" and carriage return. The stage is then moved to the limit switches, stage position counters are zeroed and stage position is returned to 20.0 in X and Y and 380.0 in focus.

3. Slide Loading Procedure

a) Insert slide in slide holder.

b) Verify that the microscope power switch is on.

c) Raise condenser, adding oil if required.

d) Add oil on top of the slide.

e) Select the proper objective lens and bring the image into coarse focus.

f) Adjust the magnification turret switch.

g) Adjust the light level for a white level of 70% on the waveform monitor.

h) Locate a chromosome spread on the slide and bring it in focus under the objective.

i) With the video white level at 70%, adjust the spread detector area threshold so that the chromosomes appear distinct on the thresholded video display.

j) Check to see that the AREA COUNT and SPREAD lights are all lit when the spread is under the objective.

k) Push SEARCH START button to initiate slide search.

4. Slide Search

The stage may be controlled manually by the joystick on the stage control box. After search starts the "Spread Number" display shows the number of spreads in the metaphase queue. The system will autofocus on each spread as it is found. The system will also periodically autofocus on objects other than spreads in order to maintain proper focus. In this case the spread light will not be on during autofocus. The "Spread Number" display is incremented each time a spread is located. At any time during the search it may be temporarily suspended with the "Search Halt" button. While the search is halted the operator may move the spread with the joystick, for example to bring a spread that would otherwise be missed under the objective for detection. The search may be resumed with the "Search Resume" button. The "Focusing" lamp lights during autofocus.

Since the "Search Halt" key can also stop the autofocus operation, the "Search Resume" key may have to be pressed twice, once to resume the autofocus and then again to resume the search. If console switch 11 is up the search will halt every time a spread is detected. "Search Resume" will continue the search.

When a sufficient quantity of spreads has been located the search may be discontinued by pressing the "Edit Start" key. If the spread queue reaches 300 "Edit Start" is initiated automatically. Normally both search and edit are done at 63X and there is only one edit. It is also possible to search at 40X and perform a low magnification edit at 40X followed by a high magnification edit at 100X.

"Edit" moves the stage to each spread location saved in the metaphase queue and initiates an autofocus sequence. The operator may reject the spread via the "Reject" button before the autofocus sequence finishes and the stage will automatically move to the next spread in the queue. If the autofocus sequence is allowed to finish the "Operator Action" light comes on and the system waits for the operator to press the "Accept" key, the "Reject" key, the "Next" key or the "Last" key. Normally the operator will center a spread he wishes to accept under the objective. He may give the spread a quality rating by pressing the "Accept" key a specific number of times. A convenient rating scheme is to use one for a cell that is marginally good enough for counting, two for a good countable cell, three for a cell of marginal karyotyping quality, four for a good karyotyping cell and five for an excellent cell. When the Edit phase is over the cells will be displayed in order of highest rating first.

When the "Reject" key is pressed the stage is moved to the next spread. After a spread has been accepted the "Next" key causes the stage to move to the next spread. The "Last" key causes the stage to move to the most recently accepted spread to re-examine the cell and possibly modify its rating. The operator may discontinue the Edit procedure when sufficient spreads have been accepted. The edit finishes automatically at the end of the metaphase queue. Each time a spread is accepted the scan queue is incremented by one as indicated by the "Scan Queue" display. When the edit is finished the scan queue is saved on disk in the event it might be necessary to restart.

5. Scanning

The stage returns to the earliest of the highest rated cells and initiates an autofocus. The message "Enter Scan ID" is typed on the DECWRITER. At this point the operator will normally change to the 100X objective in preparation for scanning. The light level is readjusted for a white level of 70% on the waveform monitor. Non-uniformity of illumination can be detected in one direction on the video waveform monitor, and in the other direction using the profiler on the image digitizer. Adjustments can be made to the condenser centering as required to make the illumination uniform. The spread image can be made to cover the entire field by selecting the proper combination of objective power (63X or 100X) and variable magnification turret power (0.8X, 1X, or 1.2X). Next focus the spread automatically using the "Focus" key or manually if necessary.

At this point the operator may execute options in response to the scan message "ENTER SCAN ID". If the spread is not in view, pressing "Search Start" will initiate a spiral search which may be controlled by "Search Halt" and "Resume". The operator may now enter optional identification data, as follows:

a) Type CR to scan without special ID (normal case).
b) Type PQ to print the scan queue on the line printer.
c) Type A to abort this spread.
d) Type Z to abort this spread and zero the scan queue.
e) Type EX to exit from scan without scanning (use old disk data).
f) Type DS for a dummy scan (scan without changing the disk data).

The message "ENTER PARAMETERS (SL,EL,SS,ES)" is typed on the DECWRITER. The carriage return will initiate a scan. Alternatively the operator may exercise options as follows.

The data percentage used in calculating the thresholds may be changed and/or a partial field may be specified. Type DP,N to change the data percent from its default value of 60. For example DP,70 would better separate touches on a heavily stained spread. DP,50 would avoid cutting apart lightly stained chromosomes. The partial field may be entered as SL,EL,SS,ES. For a full scan with the normal data percent, type CR.

Use the profiler to locate the darkest point in the image and set the ZERO control on the SDS Panel so that it is just within the digitizing range. Then locate the brightest point in the image and use the coarse and fine RANGE controls to place it just inside the digitizing range. During the scan the DECWRITER types out the stage coordinates for verification purposes. If Console Switch 1 is up the thresholds of each sector are typed on the DECWRITER. Ordinarily this option is not used.

6. Spread Interaction

When the scan is completed the DECWRITER types "CHECK SPREAD". At this point the operator may exercise keyword options. The operator may type "H" (Help) followed by carriage return to produce a brief listing of the key words and their function. If the cursor requires calibration it may be done using the "S" option. This causes fiducial marks to be generated in the upper left and lower right hand corners of the grayscale display. The operator then moves the cursor first to the upper left mark and then to the lower right mark responding each time with a carriage return. The program uses this information to generate the offset values required to maintain calibration between the displayed image and the cursor.

If the cell is to be karyotyped, obvious cuts should be made first. Move the cursor to one end of the cutting line type "C" and carriage return. Then move the cursor to the other end of the cut and type carriage return. The system will then draw the cutting line visably on the grayscale display and it may be checked for accuracy. If the cut is improperly placed, the "E" option can be used to erase the cut. After obvious cuts have been made, execute the "Q" option to get a quick count of the cell. Each object found is flagged witl a white dot. This points up the need for further cuts and joins. Joins are done in the same way as cuts except executing the option "J".

If well separated chromsomes are not properly flagged, this may mean improper threshold setting in that sector. This can be checked by moving the cursor to the chromosome in question and typing "T". This causes the sector boundaries to be marked at the right edge and bottom edge of the image and the threshold value and data value for that sector are typed on the DECWRITER. The threshold may be changed using the "T" option. A new threshold may be entered directly followed by carriage return. If no threshold change is desired, a carriage return or another command may be entered. The "B" option may be used in the same way to change the background gray level.

If the scan was improper due to improper framing or digitizer level setting, the "RS" option can be used to initiate a rescan after the corrections have been made. At any time when the spread is deemed unsatisfacotry the "A" option may be used to abort.

The U,D,L, and R options may be used to move the cursor up, down, left or right respectively in one pixel steps. The "OT" option may be used to modify the threshold for individual objects. The options "I" and "N" may be used to generate a fresh display of either the "initial" (unnumbered) or "numbered" spread respectively.

Once all necessary cuts and joins have been made and the spread is accepted for karyotyping the operator types carriage return. If the cell is only to be counted the operator will usually perform a quick count and then correct the count using the options "M" and "X". To do this position the cursor over uncounted (missing) chromosomes and type "M" to add them to the count. Similarly, one may use the "X" option to eliminate nonchromosomes from the count. If large numbers of additional counts are required, the "K" option may be used. In this mode the cursor has moved from one "missing" chromosome to the next. Each time the cursor stops a missing chromosome at that position is added to the count. To exit the "K" option, move the cursor directly to the lower right hand corner of the display. Inadvertent counts may be erased by moving the cursor to the upper right hand corner of the display. The "Z" option may be used to zero the chromosome count for a restart. For counting purposes the "F" option is used to indicate that a spread should be finished as a count only cell. This causes both a raw spread and a numbered spread to be displayed on the hard copy output device. If the "SM" option is used the program goes directly to the karyotyping phase operating on a previously stored rotated chromsome file. The object measurement routine "MOB" is skipped.

7. Analysis

If the spread is to be karyotyped it then goes into the analysis queue. The analysis queue may contain a maximum of three cells. If there are additional cells to be scanned and the analysis queue is not full the stage moves to the next spread in the scan queue. The previous procedure is then repeated on that spread. This is continued until the analysis queue is full or all spreads have been processed in this manner.

When analysis begins, a message is typed indicating which cell is being processed. After approximately one minute the spread is displayed with numbers and the "CHECK SPREAD" message is typed. The options are as previously described. Normally the number of objects will agree with the previously executed "Quick Count", but if errors occur they may be corrected at this stage. When this interactive phase is completed, about thirty seconds are required to produce and display a karyotype. At that point the message "CHECK KARYOTYPE" is typed on the DECWRITER. At this point the operator may correct measurement and classification errors.

8. Karyotype Interaction

First the operator should check for improperly isolated or improperly thresholded objects that have escaped the previous interaction. The option "RF" may be used to return to the object location routine. Improperly rotated chromosomes may be corrected with the "R" option. The cursor is first placed at one end of the true axis of the chromosome and "R" and carriage return are typed. The cursor is then moved to the other end of the chromosome axis and the carriage return typed again.

The centromeres are displayed as bars on either side of the chromosome. Centromere position may be moved up or down by first placing the cursor on the chromosome at the proper vertical position and then typing "C". If the chromosome is upside down the option "F" is used to move the centromere and "flip" the chromosome simultaneously.

The above options input corrections to the program so that the chromosomes will be modified when the karyotype is next displayed. When all centromere and rotation errors have been corrected, the operator may type carriage return to get a new karyotype with the chromosomes reclassified on the basis of their corrected measurements.

The "M" option may be used to move chromosomes from one slot to another in the karyotype. The cursor is placed first in one slot and "M" is typed. The cursor is then moved to another slot and a carriage return typed. This will cause the chromosomes in the two slots to be interchanged. This is indicated on the screen by a dark line drawn to connect the two chromosomes. If one of the slots is empty the chromosome will be moved into the empty slot. The "X" option may be used to delete a chromosome from the karyotype. The "P" option may be used to push a group of chromosomes right or left. This is a circular end-around the shift. For a right push the cursor is placed over the leftmost chromosome of the group to be pushed and "P" is typed. The cursor is then moved to the rightmost chromosome in the group and carriage return typed. This will cause each chromosome to be shifted right one slot except the rightmost will be shifted into the leftmost slot. If the cursor is moved from right to left during the push option, the shift will be left end-round.

Alphameric label information may be added using "L" option. Label information is typed on the same line. The karyotype may be aborted at any time using the "A" option. Also the cursor may be calibrated to correct for drift using the method previously described. "U" and "D" may be used to move the cursor up or down one pixel. This is convenient for making centromere adjustments. The "L" and "R" options are not functional. The option "DS" causes the numbered spread to be displayed for reference purposes.

If rotation of a chromosome fails to produce proper orientation, the chromosome must first be put back into its original orientation before it can be rotated again. This is accomplished by performing a "null rotation" in which the cursor is not moved during the operation.

All the moves may be nullified by using the "KC" option. Similarly, the "MC" option nullifies all previous rotation and centromere corrections on this spread. The operator may enter the patient's sex by using the "MA" or "FE" options. This is useful when a patient was originally indicated as unknown sex. The "NX" option produces the annotation corresponding to a homogeneously stained spread. In this case only group information is printed and homologous pair headings are deleted.

For homogeneously stained spreads the above options are sufficient to correct errors and produce a proper karyotype. When all the corrections have been made the operator types a carriage return to get a corrected karyotype display. When this is approved, a further carriage return causes the karyotyping procedure to be finished. Annotation is added to the image and it is formatted for output on the hardcopy display device.

For banded chromosomes there are two classifiers which may be executed at the operator's option. The hybrid classifier requires the chromosomes to be properly placed in groups before its execution. The Fourier classifier requires only that centromere position be correct. Console Switch 7 must be down for the hybrid classifier and up for the Fourier classifier. The "BC" option causes the appropriate banded classifier program to be executed and produces a display of the karyotype. The option "QB" differs from BC only in that it causes calculation of Fourier coefficients for the C group only. The "QB" option should be used only with the hybrid classifier. The "RB" may be used to rerun the banded classifier. This is useful when executing both the hybrid and Fourier classifier for comparison purposes. "RB" is useful in that it avoids recomputation of Fourier coefficients, thus saving time. The "WA" option may be used to generate a display of the staining profile waveforms of the chromosomes rather than chromosome images themselves. When "WA" is executed the chromosome images are destroyed and replaced by their waveform silhouettes. Thus this option should be used only after a standard karyotype has been produced. Similarly, "AX" causes the axis of each chromosome to be superimposed upon its image. Chromosomes considered by the program to be bent are fitted with a parabolic axis and this option can be used to check the accuracy of that fit.

If the banded classifier fails to produce an error-free karyotype, the "M" option may be used to move chromosomes from slot to slot as previously described. If Console Switch 0 is up, the chromosome classification information is produced on the line printer. For each chromosome the value of the distance function is printed for each homologue type. As before, when the operator approves the karyotype, a carriage return causes the display on the hard copy output device.

9. Keyboard Request

Pressing the keyboard request key causes the DECWRITER to print the response "ENTER REQUEST". The operator may then request a number of operations. A request of "C" initiates the microscope calibration procedure previously described. The "A" allows the operator to abort the spread currently in the analysis phase at any time. The "Z" option allows the operator to zero the scan queue, thus allowing a new search to begin. The "S" option allows the operator to scan a cell which was located independently of the search procedure. Optionally, he may enter the XY coordinates of the cell and thus command the stage to move to the cell before scanning. The "R" option may be used to restart analysis, scan, and/or hard copy output. The system operates in a conversational mode to allow the operator to restart only those phases he desires.

When restarting with a saved queue and a slide that has been remounted, the operator may adjust stage coordinate offsets as required by using the "Q" option.

The option "D,N" allows the operator to restart the analysis at Phase N. For example, D, 10 causes the analysis to restart at the check karyotype phase. The "E" option calls the text editor program and causes it to be executed in the analysis partition. This allows text editing to proceed simultaneously with slide search.

The "PR" option causes the spool of patient reports (one page per patient) to be listed on the line printer. Similarly, "PL" causes the patient listing to be printed. The patient listing is a one page summary of the day's activities (see Table 2-1).

10. Statistical Analysis

Programs CSTAT and SPLOT may be run directly under the DOS monitor. Their operation is described in Section III.

11. Power Down Procedure

a) Get the patient report or patient list.
b) Put enable/halt switch on halt.
c) Push run/load key on all 3 disks to load.
   Caution --- This step should always be done before turning power off. Otherwise, damage to the disk may occur. Be sure to push the run/load key and not the power key. Never turn power off on the individual disk drives, as this can also damage the disk.
d) Turn off Hughes memory, Conrac monitors, hardcopy, and microscope.
e) Turn key to off position.
f) Turn off air-conditioner.

Table 2-1. Summary of Options

Check Spread * H

Type one of the following keywords to select an option:
Q - quick count
C - cut apart a touch (position cursor first)
J - join two pieces together (use cursor)
T - change threshold (use cursor)
B - change background (use cursor)
S - set up the cursor to correct for drift
A - abort this spread
RS - rescan
F - finish this spread (no karyotype)
F,NN - finish this spread, it has NN chromosomes
I - display the initial (un-numbered) spread
N - display the numbered spread
E - erase the last cut or join request
U,D,L, or R - move the cursor up, down, left, or right
K - interactive count with cursor and bell
M - add a missing number (only for counts)
X - remove an extra number (only for counts)
Z - zero the chromosome count
If spread is OK, type carriage return.

Check Karyotype * H

Type one of the following keywords to select an option:
C - change centromere (use cursor)
F - flip and change centromere (use cursor)
R - rotate chromosome (use cursor)
M - move chromosome to another slot
X - remove chromosome from karyotype
P - push a group of chromosomes right or left
L - add a label (type label on same line)

A - abort

S - set up cursor to correct for drift

U or D - move cursor up or down

RF - rerun FOB

DS - display spread

BC - call the banded classifier

KC - clear CLASFY parameters

MC - clear MOB parameters

MA or FE - male or female

NX - no X spearation from C group

If karyotype is OK, type carriage return.

Keyboard Requests

C - calibrate microscope (lower condenser and stage before request)

A - abort current analysis spread

PR - print patient report (one page per patient)

PL - print patient listing (all on same page)

Z - zero the scan queue (allow new search to start)

S - scan (increment the scan queue)

S X,Y - scan the cell at coordinates X,Y

R - restart analysis, scan and/or hardcopy

Q - queue coordinate adjust (when restarting with old queue)

D,N - debug (start with phase N)

E - call the text editor (allows simultaneous search and text editing)

12. Error Messages

a) A002 46600 - printer is not ready. Ready it and type go.

b) A002 52140 - tape is not ready.

c) A002 15270 - one of the disks is not ready.

d) A101 - hardcopy device is not ready. Ready it and type go.

e) No objects found - type R in INTL to display the raw spread.

f) Check thresholds, but you will probably have to rescan.

g) F342, F374 or any other F message is a fatal error.

h) Check with system programmer.

i) If not available, type "MO 2773Ø" which will type out the contents of location 2773Ø.

j) Respond with LF until location reaches 3ØØ1Ø.

k) If there is a location after the F message, type out the area around that location with MO and LF.

l) Type "KI" to kill CALMS and try to restart.

For console switch setting, see Table 2-2.

Table 2-2. Console Switch Settings

0 - Up for line printer output of object threshold information and banded classifier information.
1 - Up for typewriter output of sector thresholds calculated by SCAN.
2 - Up to allow hardcopy rerun.
3 - Up for fast display on gray scale.
4 - Up for timing informaiton.
5 - Up for tape output of masked picture.
6 - Up for fast arrows during quick count.
7 - Up for full Fourier classifier, down for Hybrid classifier.
8 - Up to inhibit Fourier classifier, but allow banded measurements.
9 - Up to inhibit ABNORM.
10 - Up to halt in SEARCH each time a spread is found.
11 - Up for hardcopy fast speed, down for slow speed.

The normal switch setting is switches 3, 6, 9, 10 and 12-17 up. This is address 77311Ø, used for the disk bootstrap.

B. MOTOR CONTROL INTERFACE

1. Preparation

In preparing the system for operation the stage should be positioned between its limit switches for all 3 degrees of freedom. This can be accomplished by the operator visually inspecting the stage and positioning it, if required, by using the Operator Stage Motor Control unit, or a computer routine can exist to establish the stage between limit switches. Once properly positioned, the computer routine to correlate the cumulative position registers to the stage position should be executed. (The CPR's merely keep track of the step movements of the stage motors. They are not directly related to the stage's absolute position.)

2. Operator Stage Positioning

The operator may position the stage by use of the Operator Stage Motor Control unit (OSMC). To be able to do so the MCI must be in Operator Mode. The OSMC has two pushbuttons for the operator control of the MCI mode. One button raises a request for Operator Mode. The MCI will grant Operator Mode whenever the computer has not inhibited the granting and the motors are not busy. The other button drops the request for Operator Mode, causing the MCI to go immediately to Computer Mode. Located near the two buttons are a light that is on when the Operator Mode Request is true and two lights that indicate which mode the MCI is in.

The OSMC has a joystick and 4 pushbuttons for operator control of the X-Y positioning of the stage. The joystick is a rate device. That is, the further it is pushed the faster the stage will move in the indicated direction. The 4 pushbuttons are for single steps. Pushing and releasing a button causes the associated motor to move one step in the indicated direction.

The focus is controlled by a dual speed, two direction bat handle switch for slewing and 2 pushbuttons for single stepping. The bat handle has a bar located just beneath it. When the bar is depressed the bat handle operation will slew the Focus motor at the higher speed.

Whenever a stage limit switch is encountered the drive from the operator unit that would move the motor past the limit switch is inhibited and a light associated with a move in that direction is lit on the unit's panel.

There are 3 decimal indicators for the stage position located on the CALMS system front panel. The X and Y positions are indicated in 10's of microns and the Focus position in 10ths of microns.

C. SPREAD DETECTOR/AUTOFOCUS UNIT

1. Controls and Indicators

This section contains an explanation of the function and operation of the various controls and indicators. The controls may be functionally separated as: panel meters, threshold controls, and display status indicators. Figure 2-1 shows the front panel.

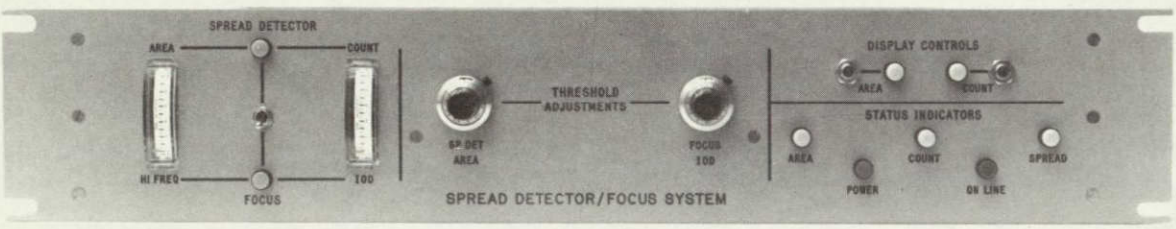


Figure 2-1. Front Panel

Visual indication of the value of the spread presence parameter or focus parameters is provided by means of two vertical edgewise panel meters. A toggle switch is used to select either SPREAD DETECTOR or FOCUS mode as indicated by the appropriate light. In SPREAD DETECTOR mode, AREA and COUNT are displayed on the meters. AREA is an indication of the total portion of the field of view which is above threshold density. COUNT is the number of valid threshold crossings (0 volts = 0, 10 volts = 255). In FOCUS mode, the two focus parameters (HF and IOD) are displayed in the same manner as the COUNT parameters.

Threshold density adjustments are made by means of two ten-turn potentiometers with vernier dials. The control marked "SP DET AREA" controls the threshold density for the spread presence parameter. The control marked "FOCUS IOD" controls the threshold density for the IOD (Integrated Optical Density) focus parameter. The two controls are independent, thus allowing different threshold densities for spread presence and focus.

Two push buttons are used for selecting the spread detection functions to be displayed on the video output. The buttons are operated identically; the display function will toggle on or off each time the button is depressed. When the AREA function is on, the video display is white for all regions above threshold density; those below are black. When the COUNT function is on, a small white dot is displayed at the trailing edge of each valid threshold crossing.

The following is a list of the five status indicators and their functions.

1) POWER - on when +5V power is up. (Note: $\pm$15V power is not monitored but is necessary for proper operation.)
2) ON LINE - on when switch on rear panel is in the "ON LINE" position. Must be on for data to be read by computer.
3) AREA - indicates when spread presence area criterion is satisfied (data word bit 13).
4) COUNT - indicates when spread presence count criterion is satisfied (data word bit 14).
5) SPREAD - indicates AREA and COUNT (data word bit 15).

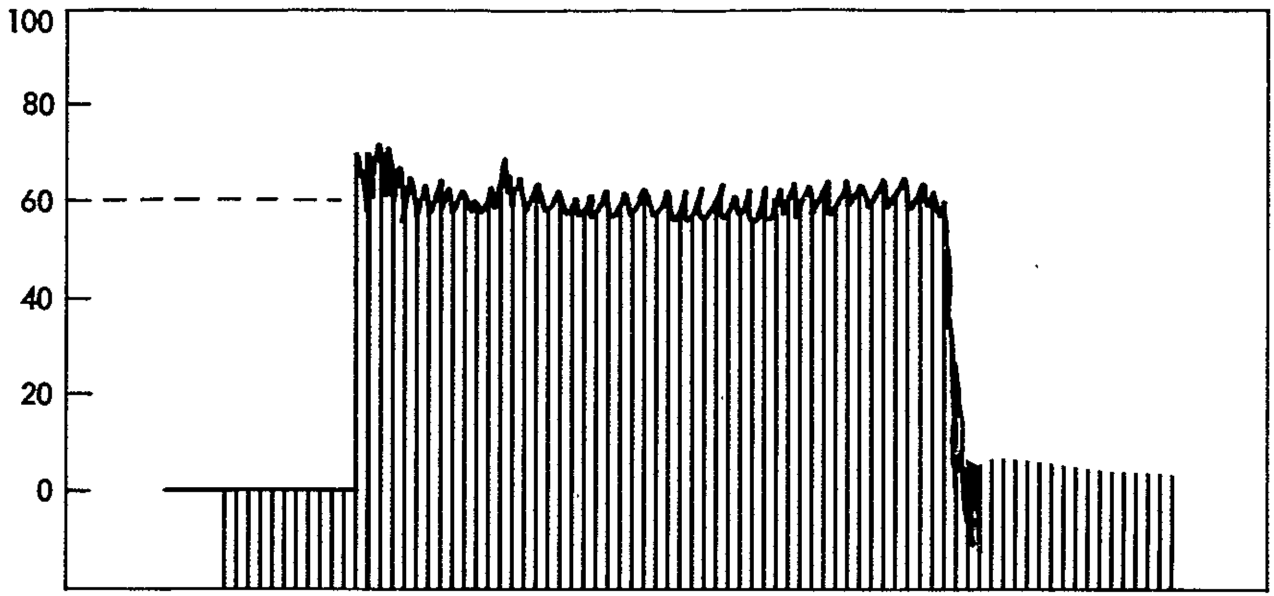
2. Displays

Two displays are associated with the system, though not physically a part of it. These displays are rack-mounted side by side and are used for set-up and calibration in addition to operational checks. One display is a standard TV monitor which receives its input from the display video output. This is used to display AREA and/or COUNT as described in section 3.1.3. The other display is a TV waveform monitor used to observe the input video waveform. Detailed operating procedures may be found in the manufacturer's literature.

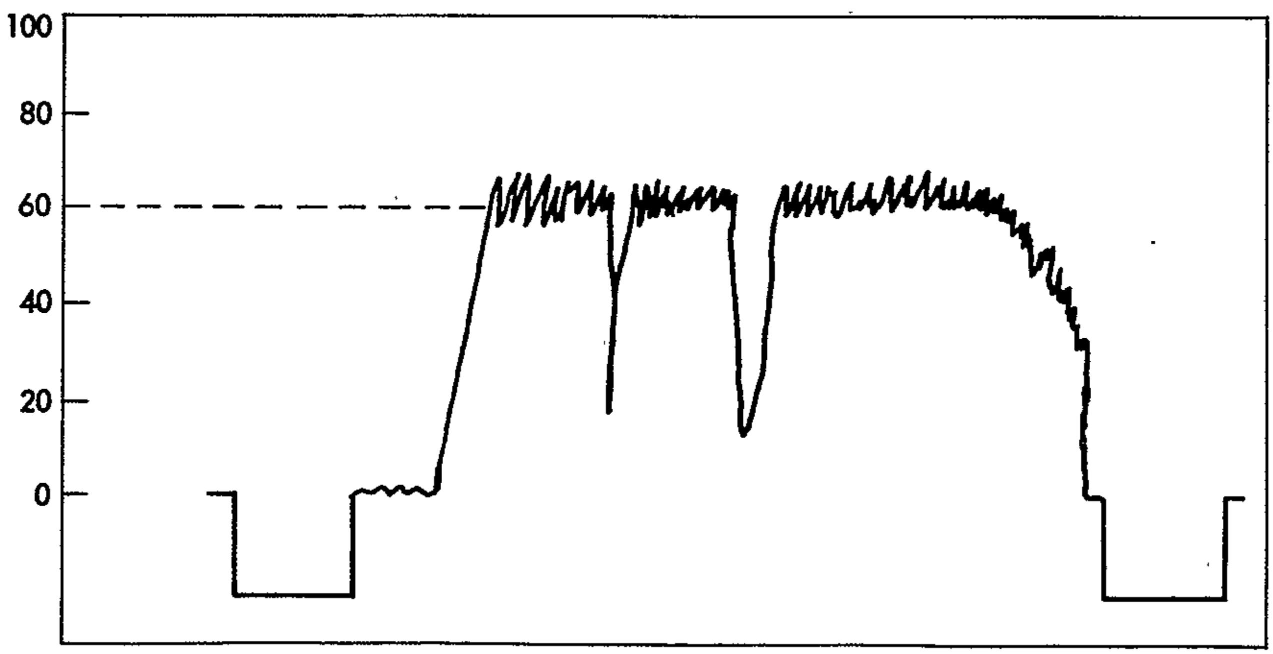
3. Setup

Setup for spread detection involves two basic adjustments. First the input video as displayed on the waveform monitor must conform to the standard conditions as shown in Figure 2-2. This is accomplished by adjusting the microscope illumination and/or TV camera (Image Quantizing System) as described in the appropriate manuals. Having obtained the standard input video, the spread detection threshold density is adjusted by means of the front panel control marked SP DET AREA. A chromosome spread image is used in making this adjustment. The individual chromosomes should show clearly on the video output display with the AREA function on. The COUNT function should indicate valid threshold crossings on most TV scan lines which cut across chromosomes. The AREA, COUNT and SPREAD status indicators should be on when a spread is in view. All should be off when viewing blank background. When viewing an undivided nucleus, the AREA indicator should be on; COUNT and SPREAD should be off. A slight readjustment of the front panel control may be required if undivided nuclei have a density close to what would otherwise be a satisfactory threshold level.

Setup for focus requires only the single adjustment of the FOCUS IOD threshold control on the front panel. With the panel meters in the FOCUS mode, and an in-focus chromosome in view, the FOCUS IOD control should be adjusted to give a reading of about 9 volts on the meter (IOD). Moving the stage in and out of focus should indicate a peak in the meter reading at best optical focus without saturation or the meter going over 10 volts. The HI FREQ meter should give the same indications though not giving the same readings. It is best to try several spreads before determining the final operating setting.



(a) WAVEFORM MONITOR-FIELD DISPLAY



(b) WAVEFORM MONITOR-LINE DISPLAY

Figure 2-2. Video Input Standard Conditions

D. INTERACTIVE GRAYSCALE DISPLAY

Operating Procedures

The operator may control the cursor via the switches and joystick of the Operator System Control panel whenever the panel's Operator Mode light is on. The cursor may be turned on or off and be made to flash or remain steady by the two associated toggle switches. (There is a third switch for crosshair/dot cursor element control which is not implemented at this time.) The cursor's position is controlled by a joystick. The joystick is a rate device. The further it is pushed off-center the faster the cursor will be moved in that direction. When the joystick is released it will return to its mechanical center and the cursor will remain where it was positioned.

E. HARDCOPY INTERFACE

This is a description of the operation of the hardcopy interface. A block diagram is shown in Fig. 7-2. The test panel appears in Fig. 2-3. Recorder operation details may be found in the Alden Electronics Model 9273/JPL instruction manuals.

1. Modes of Operation

a) OPERATE - Operation controlled by PDP-11/DR11-B.

b) TEST - Operation controlled by the operator to check the hardcopy recorder and verify recorder performance.

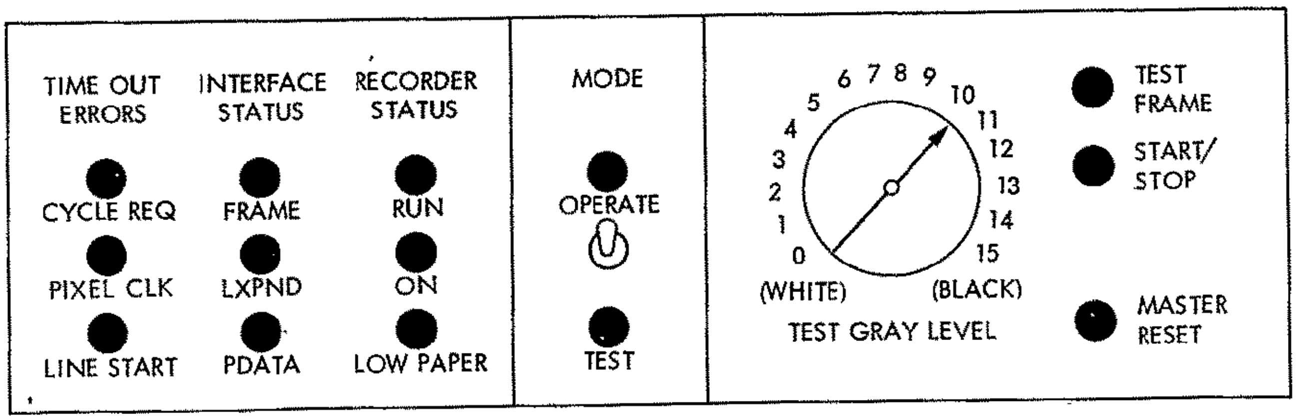


Figure 2-3. Hard Copy Test Panel

2. Controls and Indicators

1) Test Mode Controls - functional only in TEST.
   a) TEST GRAY LEVEL - selects the desired gray level (0-15) by means of a rotary switch. Zero level is white on hardcopy output.
   b) TEST FRAME - indicates a test frame in progress when on.
   c) START/STOP - controls test frame (push-to-start, push-to-stop).
2) Recorder Status Indicators - functional in both OPERATE and TEST.
   a) RUN - On when paper is moving through the recorder.
   b) ON - Indicates when recorder power is on, recorder is in DATA mode, and recorder paper is loaded.
   c) LOW PAPER - On when recorder paper supply is low. (Not operative at present, but low paper is indicated by a lamp at the recorder.)
3) Interface Status Indicators
   a) FRAME - On during output (OPERATE or TEST).
   b) LXPND - Indicates Line Expand mode (OPERATE only).
   c) PDATA - Indicates Packed Data mode (OPERATE only).
4) Timeout Error Indicators
   a) CYCLE REQ - Data not transferred from computer fast enough.
   b) PIXEL CLK - Clock pulses from recorder are too slow.
   c) LINE START - Line start pulses from recorder are too slow.
5) Reset/Initialize - depressing MASTER RESET, powering up the hardcopy interface, or receiving the Initialize (INIT) signal from the DR11-B will halt any output in progress and initialize the interface. This is also used to reset the timeout error indicators.

3. Operational Checks

Test frames are recorded to check the recorder and HCI for proper operation. The HCI must be in TEST mode for operational checks. Also, the recorder power must be on with paper loaded, and the recorder must be in DATA mode before output can start. Test frame start and stop is controlled by means o the START/STOP push button on the HCI test panel. Once a test frame has been started, the gray level may be selected by means of the TEST GRAY LEVEL switch if the recorder is in DATA mode or an electrically generated 16-step test pattern is recorded if recorder is in CALIBRATE mode. This 16-step test pattern results in 16 vertical bars of equal width and increasing density from white to black across the output in the direction of the scanning "spot".

4. Operating Adjustments

The THRESHOLD and CONTRAST controls on the recorder may require slight adjustment to obtain proper rendition of all 16-gray levels on the hardcopy output. This should be done with a test frame running and the recorder switched to CALIBRATE mode. The controls should be rotated no more than a few degrees at a time; then wait for the hardcopy to come out of the recorder and check the effect before readjusting the controls.

F. SPECIMEN PREPARATION SYSTEM

1. Dispensing of Medium

Prior to use, the Polydrop manifold, 10 ml. syringe, and the tubing and valve assemblies are washed and rinsed thoroughly in double distilled water, dried, wrapped and autoclaved. The Filamatic Pump and medium dispensing stand are set up in a laminar-flow hood and the sterilized items are unwrapped and assembled according to instructions accompanying the pump and the Polydrop manifold. The unit is primed with several strokes of the pump. The lock-nut setting for the syringe is adjusted for a delivery rate of 10 ml. (2.5 ml x 4). This volume fills one row of wells on the downstroke. On the upstroke, while the syringe is refilling, the tray is advanced manually to the next row and the procedure is repeated until all wells are filled.

2. Dispensing of Blood

This step is a manual procedure which will vary from laboratory to laboratory depending upon how blood specimens are collected (e.g. in Vacutainers, syringes, capillary tubes, etc.). Vacutainer tubes were used in this test system and the procedure described herein is based largely upon that experience.

The name, hospital number and other identifying data are recorded for each specimen as shown in the example below representing one culture tray.

NAME	HOSPITAL NUMBER	TRAY NO.	ROW	WELL NO.	SOURCE
		1	A	1	
				2	
				3	
				4	
			B	1	
				2	
				3	
				4	
			C	1	
				2	
				3	
				4	

The tubes of blood are placed in a shaker or rocker and are gently mixed for 5 minutes. A sterile Pasteur pipette with a rubber finger bulb is used to transfer one drop of blood from one tube to the appropriate well. A new pipette is used for each specimen. After dispensing the blood, plastic caps are pressed onto each well and the trays are placed in a CO_2 incubator at 37°C for 70 hrs. As the tray warms, expansion of air frequently loosens the caps; therefore, daily checks are required to press the caps back into position.

3. Colcemid Addition

This step is also a manual procedure. A dilution containing one microgram of Colcemid per milliliter is prepared in Hanks solution. Using a 1 ml. tuberculin syringe, 0.125 ml. of the solution is added to each well to give a final dilution of 0.05 micrograms/ml. The trays are first inverted several times to mix the solution and medium and then returned to the incubator for one hour.

4. Centrifugation

The trays with capped wells are placed in centrifuge carriers and are spun 350 rpm for 5 minutes in an International Centrifuge Model UV).

5. Aspiration

Following centrifugation, the uncapped trays are placed in position for aspiration. The aspirator depth control is adjusted to a point which extracts all but approximately 1 ml. of medium from each well. The vacuum and sonicator are turned on and the manifold level is pulled down and held until the 12 wells have been aspirated (approximately 3 seconds). It is advisable to perform a test run to determine whether the system is in working order before proceeding with working specimens.

After aspiration of the first tray the manifold handle is released and the tray is moved forward to the fluid dispenser. The depth control is moved to the "out" position and the manifold handle is depressed again bringing the aspiration needles into the sonicator where they are sonicated and purged for 30 seconds.

6. Fluid Dispensing

The tray is placed on the shaker platform under the fluid dispenser and the shaker is activated at a rapid rate (200 oscillations per minute) for 20 seconds. The rate and time required for resuspension should be determined for each laboratory since these parameters are dependent on the degree of packing of cells from centrifugation.

After resuspension, the shaker is slowed to approximately 100 oscillations per minute and the peristaltic pump is activated to dispense hypotonic fluid at approximately 120 drops per minute. When the wells are half-full, the shaker is stopped and dispensing is continued until the wells are 3/4 full. The trays are allowed to stand at room temperature for 15 minutes and, after recapping, are centrifuged again for 5 minutes.

The trays are aspirated, the needles are sonicated and the fluid dispenser is charged with fixative (3 parts absolute methanol: 1 part glacial acetic acid). The aspirated tray is placed on the shaker platform and the shaker is run at approximately 200 oscillations per minute for 10 seconds. The speed is reduced to 100 o.p.m. and the pump is activated to dispense fixative at approximately 60 drops per minute. This is continued until the wells are 1/2 full and the shaker is stopped in order to avoid spillage. Dispensing is continued until the wells are 3/4 full. The wells are recapped and are processed through centrifugation, aspiration and fixation two more times. At the last aspiration, the descent stop is changed to remove all but 0.5 ml. of fixative from each of the wells.

7. Slide Preparation

Precleaned and pre-labelled slides are stacked in the slide dispenser prior to processing the specimens. The tray corresponding to the labelled slides is placed beside the slide preparation unit. The cell dispenser manifold is pressed onto the sterile needles which have been previously stacked in a rack. The manifold is lowered into the 4 wells until the needles are immersed in the cell suspension.

Pressure is applied to and released from the knob at the top of the manifold to pick up a drop containing suspended cells from the 4 wells. The manifold is then placed in the dispensing position, slides are brought forward with a pull of the lever, and the knob is depressed to drop the cells. The slides are moved ahead with another pull of the lever to the cell spreader position and the air release button is depressed to provide a blast of air. The slides are left in position to be warmed and dried by the heating elements below. During this time, the needles are removed from the dispensing manifold and a new set is picked up. When the next 4 specimens are dropped, the slides are advanced again, blown, and the previous set which were warming are moved ahead into stacking trays.

SECTION III

SOFTWARE DOCUMENTATION

A. KARYOTYPING PROGRAMS

This section contains writeups for the main programs and most of the subroutines used by the system. The reader is referred to the comments in the program listings for further details.

CALMS

Purpose: Clinical ALMS supervisor - Controls slide search, scanning, analysis and hardcopy output of karyotypes or counts.

Library Residence: CALMS. LDA[1,1]

The CALMS supervisor controls the three "partitions," search, analysis, and hardcopy.

The supervisor occupies core from 30000 to 37777 and includes the hardcopy driver. The search partition is permanently resident at locations 40000 to 46777. System subroutines are permanently resident at locations 47000 to 57777.

Scan and analysis consist of 20 phases that reside on disk in core-image format. One phase at a time is loaded into locations 60000 to 156777 and called by the supervisor. (Locations 157000 to 157775 may be used for COMMON storage.).

Each analysis phase has a unique identifying number, from 1-20. Scan is phase 1, binary is phase 2, 3tc. The data set CALMS.OVR is used to store the phases. Each phase requires 63 blocks. Program OVB is used to store a phase in CALMS.OVR after it has been linked with a bottom switch of 60000.

The following batch stream builds scan (phase 1):

```
$JOB [2,2]
$R  LINK
#DK5:PHASE/CO,LP:/SH <CALMS.STB,SCAN,EXIT,FTNLIB/B:60000/E
$R   OVB
*1
$FI
```

Similar batch streams build the other phases.

An Analysis phase is loaded into core and then called as if it were a subroutine. The disk unit, file name and extension of the current scan data set are passed as parameters. The phase must return to the CALMS supervisor when it is finished. This can be done with a return statement in a subroutine or a call to the CALMS EXIT subroutine from a main program.

The following symbols are used to define the scan and hardcopy data sets.

```
NSDS = 3        # of scan data sets
NHDS = 2        # of hardcopy data sets
SDU  = 5        scan disk unit (DK5:)
HDU  = 3        hardcopy disk unit (DK3:)
```

The scan data sets are named S1, S2, S3. The hardcopy data sets are named H1, H2. They are stored under UIC [2,2]. Allocation of data sets is done by:

```
NFSDS:      .WORD   .-.   # full scan data sets (F)

SDS:        .BLKB   NSDS  if NFSDS contains F (F>0) the first F bytes con-
                          tain the data set numbers (1=S1, 2=S2, etc)
                          ordered by time of scan.

HDS:        .BLKB   NHDS  each byte gives the status of a particular data
                          set:

                           0 = available
                           1 = in use by mask
                          -1 = full (ready for hardcopy output)
```

When CALMS calls the MASK phase, it gives the current hardcopy data set as a parameter, instead of the current scan data set. When MASK returns, CALMS calls HCOPY, unless it is already operating. Whenever HCOPY finishes, it checks to see if another hardcopy data set is full, and if so, it starts to process it.

HCOPY and SEARCH are interrupt-driven and must not call any non-reentrant DOS routines, because the routine they call might be the one that was interrupted.

OPEN results in a call to the .INIT routine which is not re-entrant because it gets buffer space for a DDB. Therefore, HCOPY and SEARCH cannot call OPEN.

CALMS initially opens all the hardcopy data sets to find their start block numbers and saves them in the HSBN table.

The CALMS supervisor flow chart illustrates its operation. the 'idle loop' starts at S10 and the program will cycle until a spread can be scanned or analyzed, or a special request has been made (see Fig. 3-1).

After a spread is scanned, the program INT1 is called. If the operator only wants to do a count, the spread will not be placed in the analysis queue, and the counting and masking are done at this time.

If the spread is to be karyotyped, it will be added to the analysis queue, but if more spreads are to be scanned (and scan data sets are available), they will be scanned before analysis begins. When all spreads on a slide have been scanned, a new slide can be searched while spreads from the previous slide are karyotyped.

Figure 3-2 details the flow of data through the various program and data sets during the karyotyping process.

The analysis loop begins at S75, and CALMS stays in this loop until the MASK phase is called (or a restart or abort is requested).

After MASK is called, CALMS starts the hardcopy partition (unless it is already running), and returns to the "idle loop."

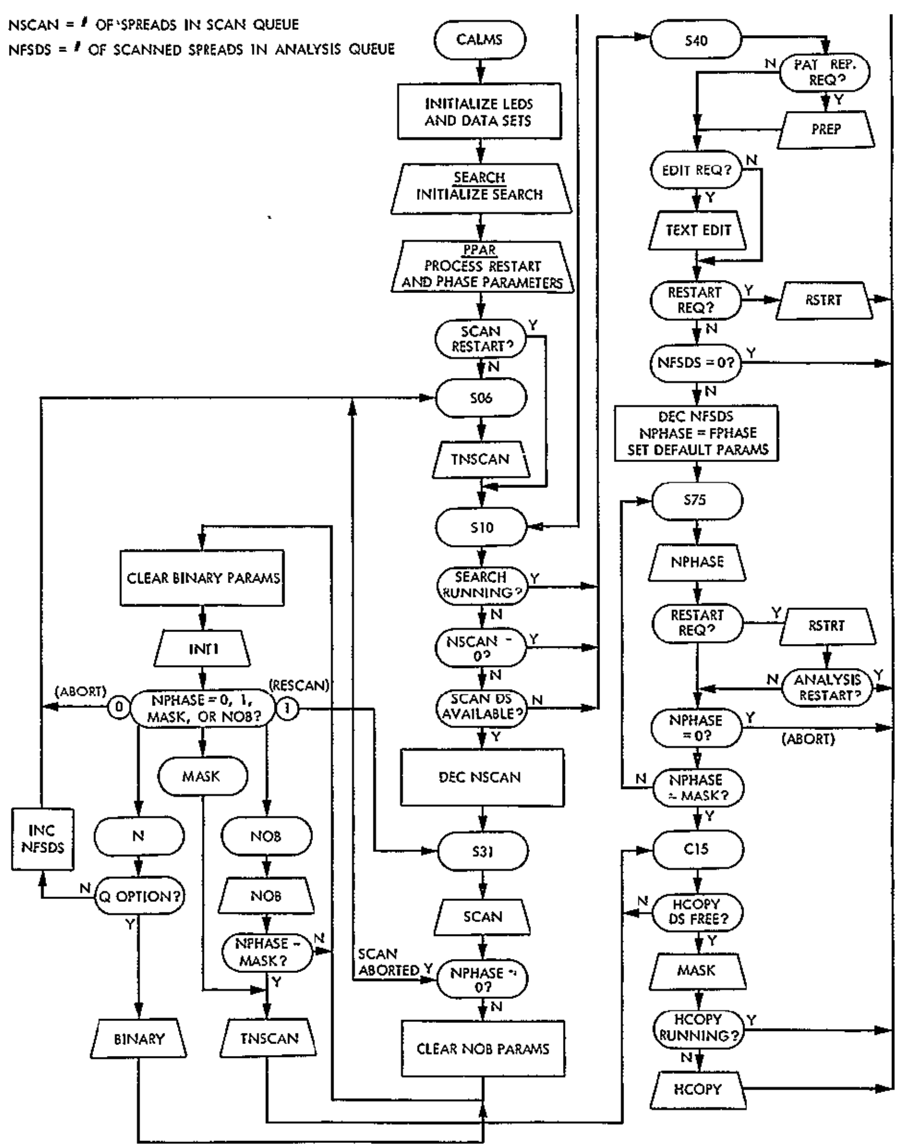


Figure 3-1. CALMS Supervisor

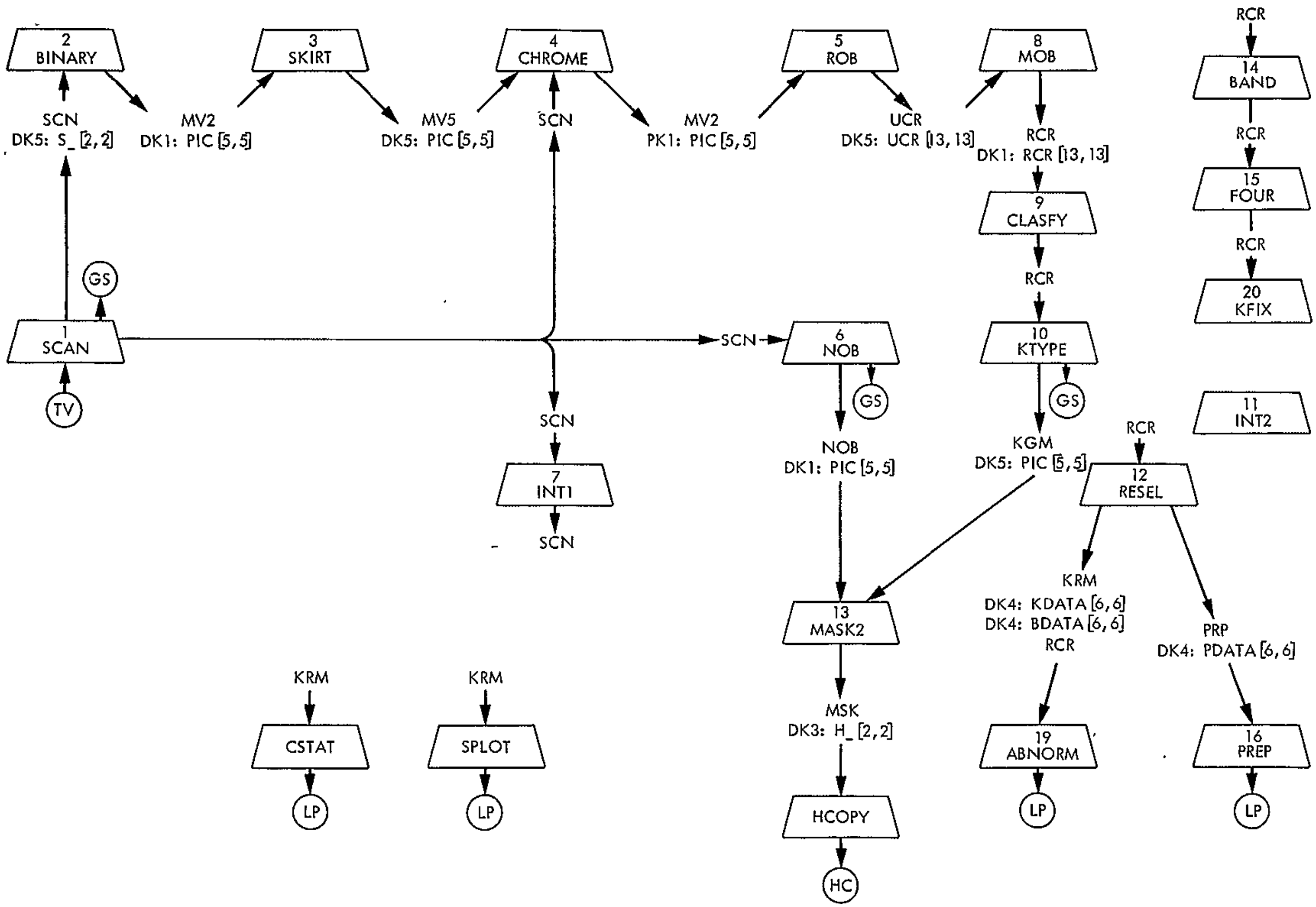


Figure 3-2. CALMS Data Flow

SEARCH

Purpose: Slide search edit, and focus. Search partition of CAIMS

Library Residence: SEARCH.OBJ [2,2]

Description: Search controls the microscope stage and handles the interrupts from the special-function keyboard and spread/focus data ready.

Initially, CAIMS calls search to set up some of the interrupts. Thereafter, search is interrupt-driven.

The operator presses search start on the special-function keyboard to start a search. Patient id, sex, slide id, and source are entered from the typewriter, before the search actually starts. The search pattern is a boustrophedon. Each step is 130 microns, and 75 horizontal steps are taken, before a vertical step is taken. Thus, the slide is searched in rows that are about 10 mm long.

Search is entered via the spread/focus data ready interrupt, after each step. If the "spread" bit is on, the X and Y values are saved in the spread queue, SPQ. Search will perform an auto-focus whenever 15 steps have elapsed since the last auto-focus, and there is something to focus on.

The operator can manually halt the search with the search halt key. He can then move to another area of the slide and resume the search by pressing search resume. Search disables the spread/focus data ready interrupt when it receives a search halt interrupt, and re-enables it for search resume.

The search is terminated when 300 spreads have been found, or when the operator presses the edit-start key.

Normally, both search and edit are done at 63X, and there is only one edit. (There is also an option to search at 40X and do a "low-magnification" edit at 40X, followed by a "high-magnification" edit at 100X.))

Edit moves the stage to each spread location saved in the spread queue and initiates an auto-focus sequence. The operator can reject the spread before the auto-focus sequence finishes, and edit will immediately move to the next spread in the queue. If the auto-focus sequence finishes, edit turns on the operator action light and waits for the operator to press "accept," "reject," "next" or "last."

The operator normally centers the spreads he wishes to accept. When the accept key is pressed, edit saves the X and Y values in the same place in the queue and flags them by setting them negative. It also increments the rating for the spread by one each time the accept key is pressed. The ratings are stored in a byte table named SPR.

When the reject key is pressed, spread rating is zeroed and the X and Y values are made positive. The stage is then moved to the next spread.

The next key causes edit to move to the next spread without altering the accept-reject state.

The last key causes edit to move to the previous spread.

The edit finishes when the end of the queue is reached, or when the operator presses edit-end. The queue is then sorted according to rating. The highest rated spread is moved to the start of the queue, and the stage is moved to this spread in preparation for the first scan. At this point, the queue and other critical information is saved, by calling WPARAM for phase one. This allows a scan restart at a later time.

GNSTS is the entry point for the "get next spread to scan" subroutine. It initiates a motor move and auto-focus on the next spread in the scan queue. CSPQ contains the current location. It also enables a spiral search, if search start is pressed. The spiral search is useful in locating a spread close to known coordinates. It takes steps of 50 microns in a spiral pattern and focuses when there is something to focus on. The operator can halt it or resume it with the search halt and resume keys.

The focus routine can be entered via the focus key interrupt, or it can be called as a subroutine via a simulated interrupt. It operates by initiating focus motor moves and executing an RTI instruction, after setting up the spread/focus data ready interrupt. When the move is completed, it is re-entered and compares the new focus value with the old one to see what the next move should be. Each lens has an initial and final step, based on its magnification. The step size is decreased until the final step size is reached. The focus flow chart illustrates the algorithm. (See Fig. 3-3.)

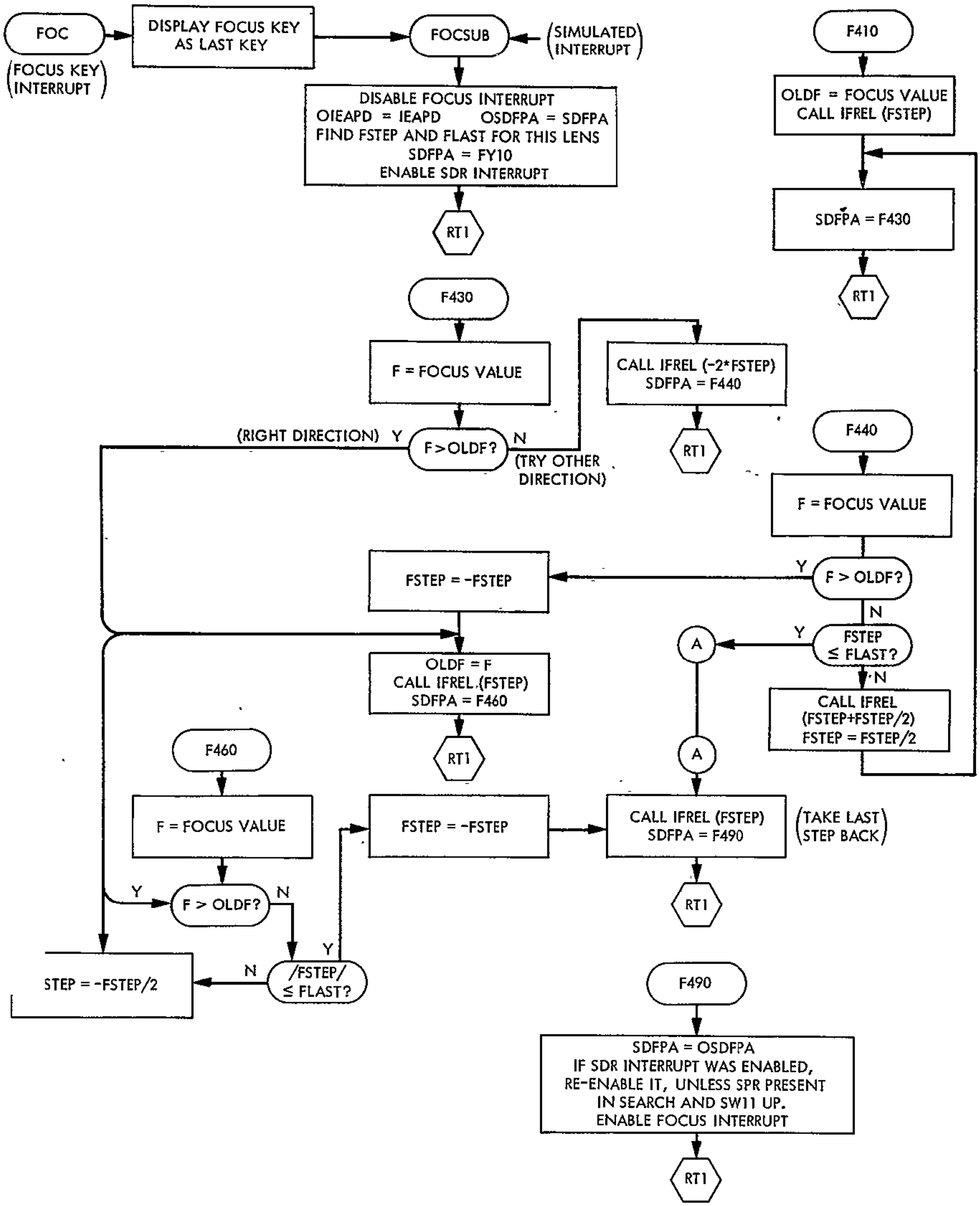


Figure 3-3. Focus

SCAN

Purpose: To scan a picture onto disk, display it on the gray scale, and calculate sector thresholds.

Library Residence: Phase 1 of CALMS.OVR

Description:

SCAN uses the SDS data camera to scan a picture onto disk. The picture is scanned by columns, with alternating even and odd TV fields, to achieve the minimum scan time of 17 seconds. Each column is assembled in core and output as a line on disk and on the gray scale. The coils on the SDS monitor have been rotated so that the orientation is the same as on the gray scale monitor.

Sector histograms are accumulated as the picture is scanned, and sector thresholds are calculated at the end of each row of sectors. The thresholds are typed out if SW1 is up. The thresholds are written after the last picture line.

SCAN sets priority 6 during the pixel digitization loop to prevent interrupts from other devices which would cause it to lose "sync". Hardcopy interrupts (which are at priority 7) are the only ones allowed, due to their critical nature. When the hardcopy is running, the SCAN takes several seconds longer.

SCAN converts pixel values of 0 to 1, and values of 127 to 126. This allows cut and join lines to be differentiated from normal data values.

SCAN stores the source code, patient ID and sex, slide ID, X and Y values, date and time of scan into the label of the output data set.

The operator may enter additional information as the SCAN ID.

The standard scan area is SL=8, EL=508, SS=2, ES=476 for a picture with NL=500 and NS=474. The operator can change these values.

See the operator's manual for further information.

BINARY

PURPOSE: To segment the chromosomes and generate an edge file containing the end point coordinates for each segmented chromosome. (See Fig. 3-4.)

LIBRARY RESIDENCE: Phase 2 of CALMS.OVR

DESCRIPTION: BINARY will read in a scanned spread and assemble a reduced core image of binary sample points. Each sample point is obtained by averaging a 2x2 pixel area. If this average is above the sector threshold, then the sample point is recorded as a 1-bit. Otherwise, a zero bit is recorded. Thus a digitized spread of 500x480 pixels is reduced to a 250x240 grid of sample points. The resulting binary image is surrounded with zero bits to provide a physical boundary to keep the perimeter walker used in the segmentation algorithm from wandering off the edge of the picture. The binary reduction is accomplished through multiple calls to the subroutines QTHR or STHR.

After the binary image has been completely assembled in core, it is scanned line-by-line for chromosomes (1-bits). Each chromosome is "segmented" by recording its starting and ending coordinates on each scan line. Provision also exists for multiple segments to occur on any given line (Fig. 3-5).

The segmentation algorithm is implemented in the subroutine SEGMNT, which scans the binary image line-by-line for chromosomes. The search is performed by ROACH, which scans each line from left to right, stopping only when it encounters a chromosome. The starting bit location of any chromosome found is recorded and control is transferred to the subroutine TURTLE. TURTLE will walk counterclockwise around the perimeter of the chromosome, recording the segment end point coordinates as it proceeds. Since the coordinates are recorded in the order they are encountered along the perimeter, they must be rearranged so that they correspond to starting and ending segment coordinates. This is accomplished by sorting the coordinates with the integer sort routine SORTIN.

After a chromosome has been completely segmented, it must be removed from the image in order to prevent ROACH from re-encountering it while scanning the next line. The subroutine ERASE will use the segment coordinates to erase (set all 1-bits to zero) the chromosome from the image.

At this point, chromosomes may be accepted or rejected on the basis of length, width, area and perimeter measurements. All chromosomes thus accepted are recorded in an edge file (Fig. 3-5) in a format suitable for input to the phase SKIRT.

PARAMETERS: All parameters are optional and may appear in any order except where specified.

AREA	followed by two integers representing the minimum and maximum allowable cross sectional areas.

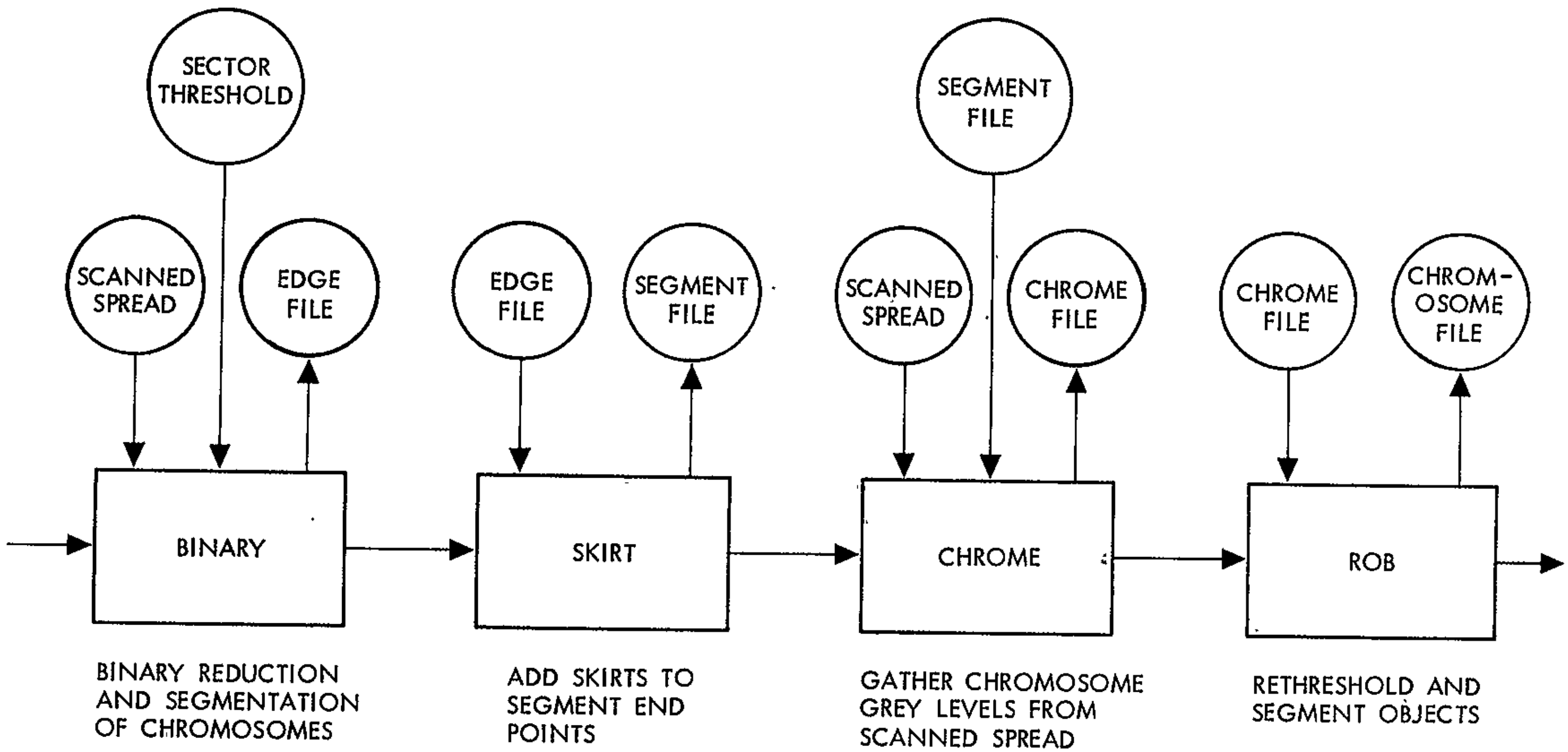


Figure 3-4. CALMS Segmentation Sequence

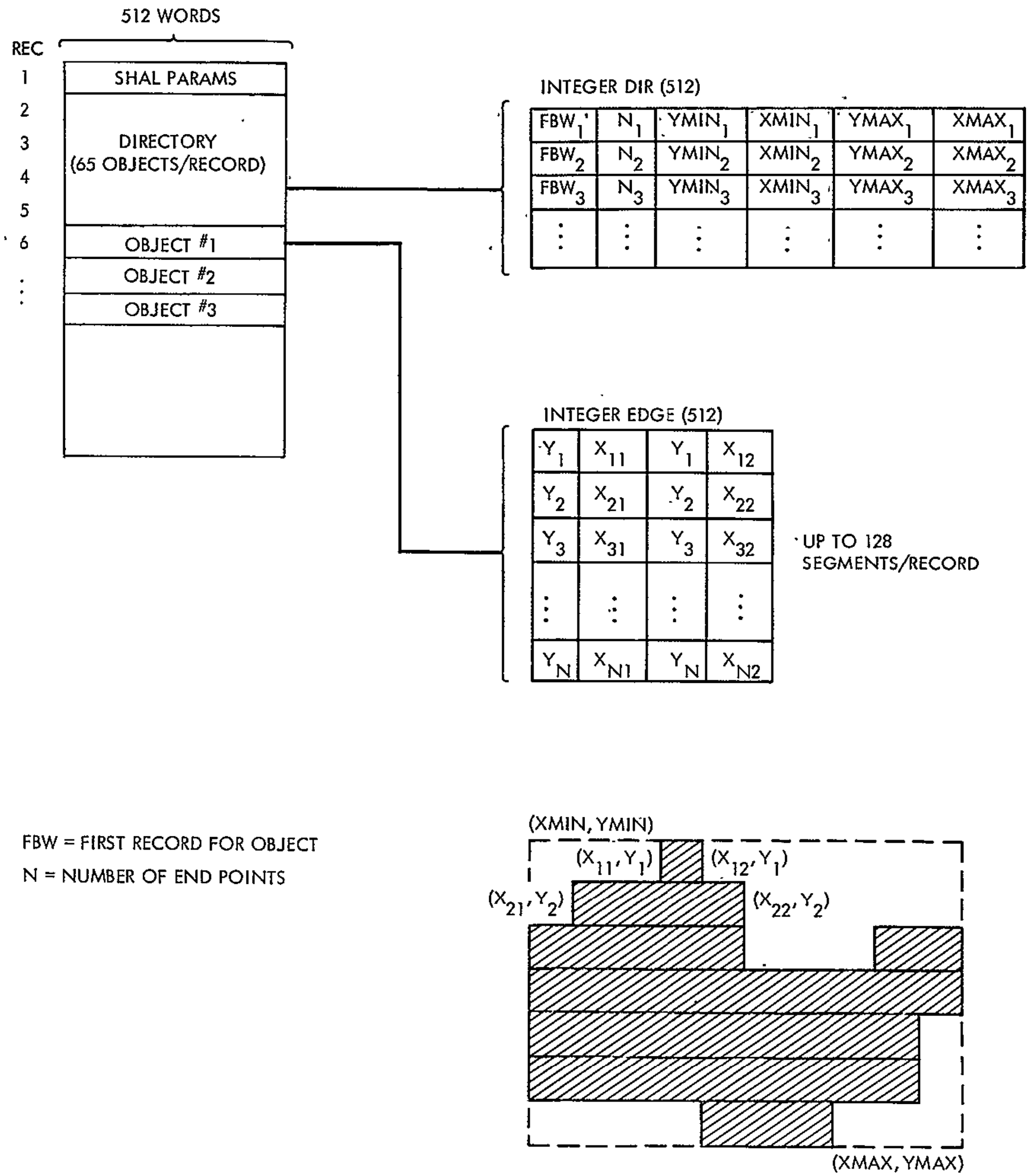


Figure 3-5. Edge File Format

BINARY
(Continued)

EP	followed by two integers representing the minimum and maximum number of perimeter points allowable.
LENGTH	followed by two integers representing the minimum and maximum allowable length.
SKIRT	followed by an integer representing the width of the skirt (in pixels) to be added to all the chromosomes during the SKIRT phase.

SKIRT

PURPOSE: To increase the cross sectional area of each segmented chromosome by recomputing the segment end points and storing the results in a segment file suitable for input to the CHROME phase.

LIBRARY RESIDENCE: Phase 3 of CALMS.OVR.

DESCRIPTION: SKIRT will increase the area of each chromosome by extending its boundary outward a uniform distance in all directions (Fig. 3-6). Each chromosome is thus skirted with marginal elements to prevent loss of data when the boundaries are recomputed during the rethresholding step (ROB phase). SKIRT requires an edge file as input and generates a segment file (Fig. 3-7).

The width of the skirt is controlled by the parameter B (number of boundary samples), which is introduced in the BINARY phase. The chromosomes are enlarged by recomputing the segment end points, adding new segments where necessary and merging segments that have grown together. The segment end points are stored in the segment file as triplets (line coordinate and starting and ending sample coordinates).

The background gray levels and thresholds for each chromosome are computed by estimating its center of mass and interpolating over the values for the four nearest sectors.

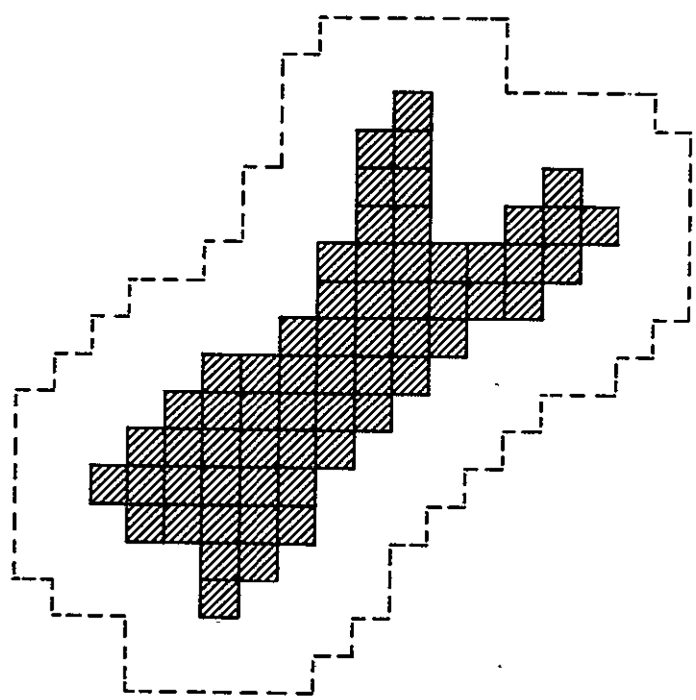


Figure 3-6. Segmented Chromosome Surrounded by Skirt

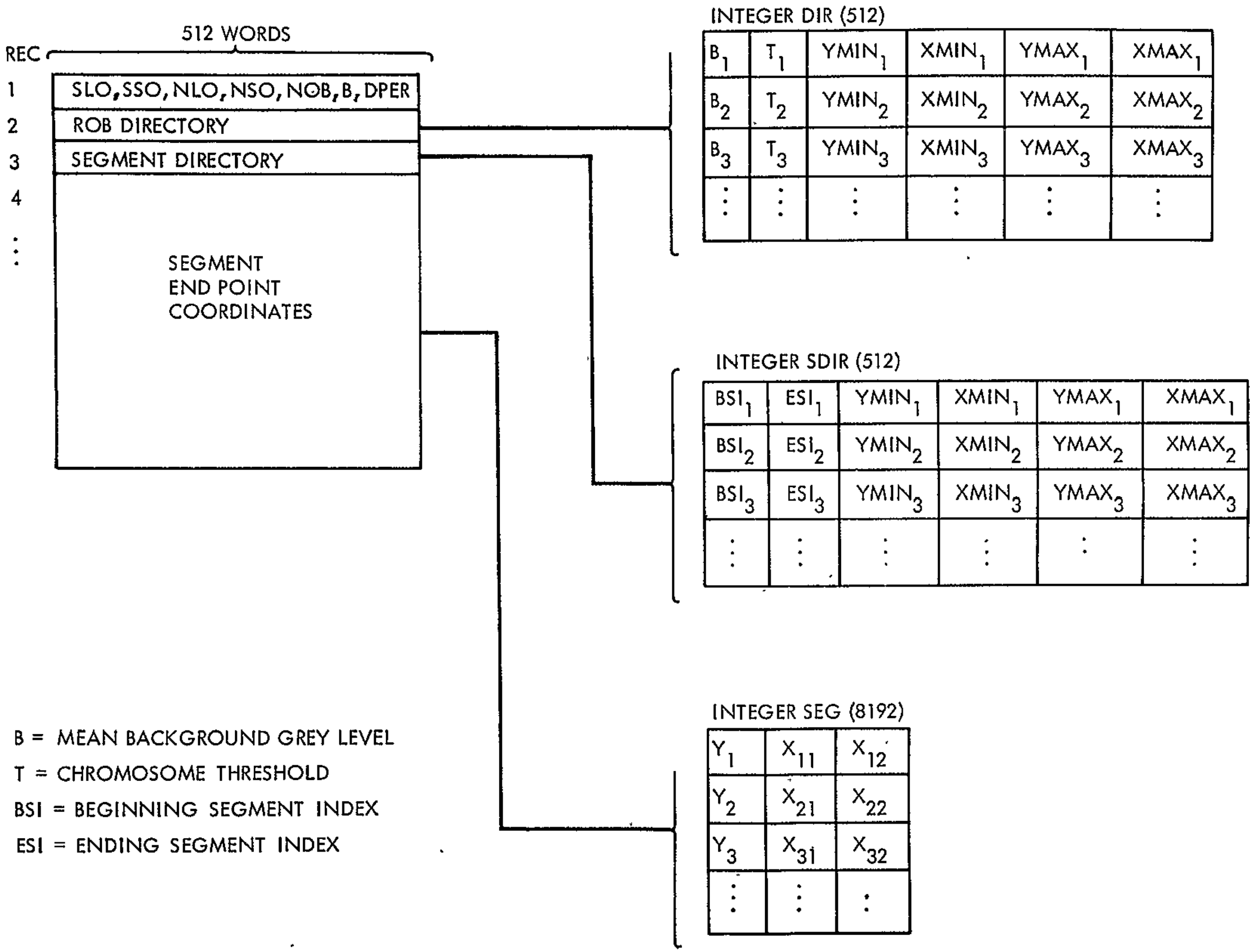


Figure 3-7. Segment File Format

CHROME

PURPOSE: To gather the gray values of the segmented chromosome from the scanned spread and to store them in a chrome file.

LIBRARY RESIDENCE: Phase 4 of CALMS.OVR.

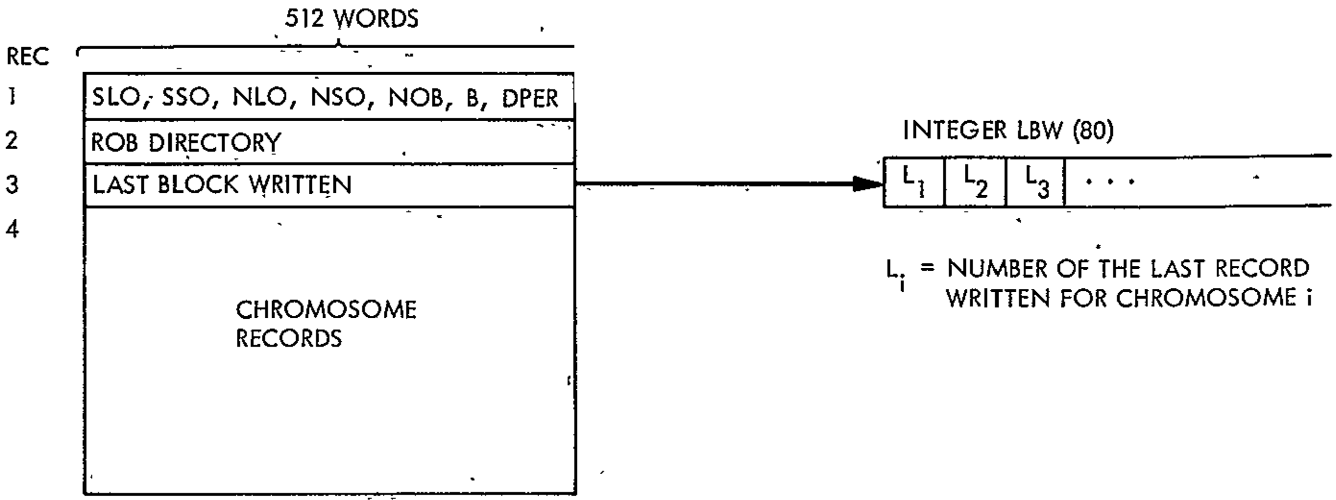
DESCRIPTION: CHROME requires as input a scanned spread and its corresponding segment file. Using the segment end point coordinates, CHROME gathers the gray values for each chromosome and stores them in a chrome file in a format suitable for input to the ROB phase (Fig. 3-8).

In order to avoid re-reading scan lines, chromosomes which appear on the same line are processed concurrently. For this reason, the gray values are stored in an intermediate buffer (CBUF) until an entire chromosome has been processed or the buffer becomes full. When all the gray values for a chromosome have been gathered in CBUF, the gray values and their associated segment end point coordinates are assembled in one or more chromosome records (Fig. 3-8) and written onto the chrome file. This task is performed by the subroutine WBUF. If the intermediate buffer becomes full, the chromosome occupying the most space in the buffer will be assembled and written out with a call to WBUF.

The intermediate buffer is partitioned into sections of a fixed size and formatted into a list structure to facilitate the allocation and release of buffer areas. The first word of each section contains the buffer index of the next section in the list (=0 for the last section in the list). The remaining words in each section is used to store grey level information.

Initially, all the sections are formatted into a single list representing all available sections. The next free section index (NFSI) points to the beginning of this list, and is updated whenever sections are removed from or added to the front of the list.

When sections are allocated to a chromosome, indices pointing to the first and last sections of the chromosome list (FSI and LSI) are maintained in a chromosome directory.



EACH CHROMOSOME RECORD HAS THE FOLLOWING FORMAT:

PBW	NSEG	Y_1	X_1	N_1	$2N_1$ SAMPLES	$2N_1$ SAMPLES	Y_2	X_2	N_2	$2N_2$ SAMPLES	$2N_2$ SAMPLES . . .

WORD	
	NUMBER OF THE PREVIOUS RECORD WRITTEN FOR THE CHROMOSOME (=0 FOR THE FIRST RECORD OF EACH CHROMOSOME)
2	NUMBER OF SEGMENTS IN THIS RECORD
3 AND 4	LINE AND SAMPLE COORDINATES FOR FIRST SEGMENT
5	NUMBER OF SAMPLE POINTS FOR FIRST SEGMENT (N_1)
6 TO $4N_1+5$	GREY LEVELS FOR FIRST SEGMENT. SINCE EACH SAMPLE POINT REPRESENTS A 2 X 2 PIXEL AREA, $4N_1$ PIXELS ARE STORED, OR $2N_1$ PIXELS EACH FROM TWO CONSECUTIVE LINES.
$4N_1+6$ TO ...	SIMILAR INFORMATION FOR THE SECOND SEGMENT

Figure 3-8. Chrome File Format

ROB

PURPOSE: To rethreshold and resegment the chromosomes and to store them in a chromosome file.

LIBRARY RESIDENCE: Phase 5 of CALMS.OVR.

DESCRIPTION: ROB requires as input a chrome file containing segment end point coordinates and gray level information for each chromosome. Each chromosome is reassembled in core and its histogram is generated. Based on its histogram, a new threshold is computed for the chromosome. Using this new threshold, the chromosomes are resegmented by applying algorithms very similar to those used in the BINARY phase, except that the algorithms are applied on the gray values themselves rather than on a binary reduction.

The segmentation process begins with a line by line scan for pixels above the computed threshold.. This task is performed by the subroutine ISEG, which records the location of any objects that it finds. The task of tracking the perimeter of the object is performed by the subroutine SOT (Son of Turtle), which records the segment end point coordinates as it walks around the object in a counterclockwise direction. The coordinates are sorted to correspond to segment end points by the subroutine SORTIN.

The segments are examined for pixels lying within the original boundary for the chromosome established in the BINARY phase. If this search fails (i.e., if the object lies completely in the skirt), the object is rejected. This is necessary to prevent fragments of neighboring chromosomes from being included in the chromosome file.

The object is then assembled into one or more chromosome records and the space it occupied in core is zeroed out. The task of moving the object is performed by the subroutine REMOVE, which may optionally contrast stretch the gray values for maximal display. The object may be rejected at this point based on area measurements. The assembled chromosome records are written onto the chromosome file and the object entered into a chromosome directory.

The first record of the chromosome file contains the following:

WORD	
1	Number of chromosomes (maximum of 60)
2-241	Chromosome directory containing the following four numbers for each chromosome: FBW = First chromosome record written YMIN = Minimum line coordinate XMIN = Minimum sample coordinate LBW = Last chromosome record written
242-302	Thresholds used for each chromosome

ROB
(Continued)

The second record contains the following:

WORD	
1-60	Line coordinate of an internal point for each chromosome
61-120	Sample coordinate of an internal point
121-180	Perimeter measure for each chromosome

The remainder of the file is composed of one or more contiguous chromosome records for each chromosome. Each such record will contain the following:

WORD	
1	Number of segments in this record
2	Line coordinate for first segment
3	Sample coordinate for first segment
4	Number of samples (N) in segment
5 to N+4	N Gray levels for this segment
N+5	Line coordinate for second segment

NOB

Purpose: To number the objects found by SEGMENT or ROB and display the picture on the gray scale.

Library Residence: Phase 6 of CALMS.OVR

Description:

NOB reads 122 words of parameters into NK, LT(60), ST(60), and FI. If FI is zero, NOB does not display the picture on the gray scale, and calls APHASE (MASKPH).

NK is the number of chromosomes and LT and ST are the lines and samples where the numbers are to be placed.

NOB reads one line at a time and adds any numbers required on that line. If LT is in order, NOB runs a little faster since it doesn't have to search the entire table for each line.

INT1

Purpose: To correct errors in object isolation.

Library Residence: Phase 7 of CALMS.OVR

Description:

INT1 is called immediately after each spread is scanned. The operator normally requests a quick count at this time. If the spread is only to be used for a count, the operator can correct for missing or extra objects and finish it.

If the spread is to be karyotyped, cuts, joins, and threshold changes are needed to correct for errors in object isolation. After the objects have been isolated, INT1 is called again to check for any remaining errors.

INT1 communicates with CALMS by calling APHASE. It writes parameters to BINARY to indicate a quick count, and to NOB to tell it to call MASK and not display the picture when finishing up a count.

See the operator's manual for detailed information.

MOB

Purpose: To orient and measure the chromosomes.

Library Residence: Phase 8 of CALMS.OVR

Description:

MOB orients each input object, accumulates IOD, area and length and calculates centromeric index by length, IOD and area. The unrotated chromosome file (UCR) is MOB's input (which is ROB's output) and the rotated chromosome file (RCR) is MOB's output.

The format of RCR is as follows:

```
Rec 1:  Word (1)      =  # of input objects (integer)
        Word (2,3)    =  Spread IOD (real)
        Word (4,5)    =  Spread length (real)
        Word (6,7)    =  Spread area (real)
        Word (8)      =  Next available record in RCR (integer)
        Word (9)      =  # of chromosomes
        Words (16-465)=  Chromosome directory
Rec 2:  Words (16-465)=  Chromosome directory
Rec 3:  Reserved for CLASFY results
Rec 4-7:  Reserved for BAND results
Rec 8 & following records:
        Rotated chromosomes images
```

The chromosome directory (Rec 1 and Rec 2) has the following format:

```
Integer CHDIR (15, 60)
        CHDIR (1, 1) - CHDIR (15, 30) on Rec 1
        CHDIR (1, 31) - CHDIR (15, 60) on Rec
```

Each entry is as follows:

```
        CHDIR (1, I) = 1st Rec. # of Ith rotated image, or zero
                       if rejected
        CHDIR (2, I) = # of lines in image
        CHDIR (3, I) = # of samples in image
        CHDIR (4, I) = Length of chromosome
        CHDIR (5, I) = IOD/8 of chromosome
```

MOB

(Continued)

CHDIR (6, I) = Centromeric Index by Length

CHDIR (7, I) = Centromeric Index by Density

CHDIR (8, I) = Centromeric Index by Area

CHDIR (9, I0 = Centromere Line

CHDIR (10, I) = Perimeter of chromosome

CHDIR (11, I) = Area

CHDIR (12, I) = P^2/Area

CHDIR (13, I) = Centromere Location Method

CHDIR (14, I) = Available for expansion

CHDIR (15, I) = Available for expansion

MOB will reject objects if they are too large or too small. The maximum allowable size before rotation is 88 x 88. The maximum allowable size after rotation is 88 x 48. The maximum area is 2000 points, and minimum area is 30 points. The minimum length and width are 5 lines and 5 samples. When an object is rejected, its area, length, and width are typed.

Originally, MOB had an option to use a skeleton method in locating centromeres. However, this method took 25 sec. longer with little or no improvement in centromere accuracy. This option was removed in order to save core space and allow a larger maximum chromosome size.

CLASFY

Purpose: To classify the rotated chromosomes into 10 groups (conventional classifier).

Library Residence: Phase 9 of CALMS.OVR

Description:

CLASFY reads in the chromosome directory produced by MOB and classifies each object. Once classification is complete, CLASFY writes the classification tables into RCR, record 3. The format is:

Word (1)	= # of samples in karyogram
Word (2)	= No object # flag
Word (3 - 12)	= Group ID's
Words (13 - 102)	= Slot ID's
Words (103 - 108)	= Initial Slot for each row
Words (109 - 199)	= Object found in each slot
Words (200 - 204)	= Center line table for each row
Words (205 - 294)	= Center sample for each slot

This table is then used by KTYPE to build the output karyogram.

Classification is based on an internal table that gives the minimum and maximum allowable centromeric indices for each length, for each of the ten groups of chromosomes. The table is called CT and is dimensioned (20, 51). The twenty entries for each length are minimum and maximum CI for A-1, A-2, A-3, B, C+X, D, E-16, E-17 and E-18, F and G+Y.

First, an initial classification is made. Then, moves are made from "heavy" groups to "light" groups. When there are several candidates for a move, the one with "maximum likelihood" is chosen.

After all possible moves have been made, the chromosomes within each group are ordered according to the slope table which describes the slope of a line that sweeps in from the right. Most groups are ordered by size. When the C+X group has 15 or 16 members, the third largest or third and fourth largest are placed in the X slots. When G+Y has five members, the chromosome with the maximum fit factor is placed in the Y slot.

The classification table can be supplied to CLASFY with the OS parameter, followed by the object numbers for the slots. In this case, CLASFY sets up the karyotype format but does not do any classifications.

KTYPE

Purpose: Builds output KARYOGRAM and displays it on the gray scale.

Library Residence: Phase 10 of CAIMS.OVR

Description:

KTYPE utilizes the chromosome directory, the classification tables and the rotated images on RCR to build the karyogram on KGM.

IBUF is a 20480 byte buffer that holds one record for each object on the current line. Since the record length is 1024 bytes, twenty objects can be accommodated.

KTYPE builds the karyogram one line at a time, inserting line segments from IBUF, object numbers, centromere marks and slot ID's at the appropriate time in the appropriate place.

INT2

Purpose: Provide operator interaction to fix karyotype errors

Library Residence: Phase 11 of CAIMS.OVR

INT2 is called after the chromosomes have been measured, classified, and displayed as a karyotype. The operator can correct rotation errors, centromere errors, and classification errors. The corrections are normally done in the above order, since a rotation error usually causes a centromere error and a centromere error usually causes a classification error.

INT2 uses WPARAM to write parameters to MOB and CLASFY and uses RPARAM to read them back to see what has previously occurred. If the operator corrects rotation and centromere errors and does not move any chromosomes around, INT2 will allow CLASFY to reclassify on the basis of the new measurements. After the operator starts making moves, INT2 tells CLASFY what the karyotype should look like and does not allow an automatic reclassification.

See the operator's manual for a complete list of INT2 parameters.

RESEL

Purpose: Save information on measured chromosomes.

Library Residence: Phase 12 in CALMS.OVR

Description;

RESEL uses the MOB output to rearrange the measurements in order of type and store them in KDATA (BDATA for banded spreads). It also writes the patient report line in PDATA.

Format of KDATA: RECLEN = 1024

Line 1 Directory Record 1 for Source 1 spreads

Bytes			
1-2	NEXT	I*2	Line # of next Dir Rec for Source 1, or 0
3-4	NUSED	I*2	# of spreads in this Dir Rec max is 85
5-854	PID(850)	BYTE	10 byte patient ID for each spread, or 0
855-1024	LINE(85)	I*2	Corresponding data line # for each spread

Line 2 Directory Record 1 for Source 2 spreads

Line 15 Directory Record 1 for Source 15 spreads

When "NUSED" becomes 85, next available line # will be inserted into NEXT. Then the line in NEXT will be the next directory record for this source.

Line 16-500 Data Records and Directory Records, if necessary

Bytes		
1-64	LABEL 1	(First 64 bytes) source, patient, sex, slide, X, Y
65-84	LABEL 2	(First 20 bytes) scan time
85-104	LABEL 3	(First 20 bytes) scan ID
105-124	LABEL 4	(First 20 bytes) diagnosis

RESEL
(Continued)

Bytes			
125-126	NC	I*2	# of chromosomes in the karyotype
127-128	LSUM	I*2	Length sum (not normalized for 46)
129-132	ISUM	REAL*4	IOD sum (not normalized for for 46)
133-136	ASUM	REAL*4	Area sum (not normalized for 46)
137-144	UNUSED		
145-224	ON(80)	BYTE	Object #'s for types 1-24, 25-30, 31-40, or 0
225-304	ONL(80)	BYTE	# lines for each object
305-384	ONS(80)	BYTE	# samples
385-464	LEN(80)	BYTE	Length (adjusted for bend) - unnormalized
465-624	IOD(80)	I*2	IOD/8 - unnormalized
625-784	AREA(80)	I*2	Area
785-864	CIL(80)	BYTE	CIL
865-944	CID(80)	BYTE	CID
945-1024	CIA(80)	BYTE	CIA

Records 2-4 for Banded Data

1-1632	OCFOUR(51,8)	REAL*4	C for types 1-24, 25, 26
1633-3060	OPHI(51,7)	REAL*4	PHI for types 1-24, 25, 26

Negative Source = Banded spread and uses DK4:BDATA[6,6]

MASK2

Purpose: To combine two pictures and add a border

Library Residence: Phase 13 of CAIMS.OVR

MASK2 combines the numbered spread and karyotype into a single picture formatted for the hardcopy. The output is written on disk, with an option to also write it on tape if switch 5 is up.

The picture on disk is written in hardcopy format, with four bits for each element, and the picture on tape is written with eight bits for each element. Gray scales, reference masks and annotation are added to the picture.

MASK2 is also used to combine the numbered spread and the raw spread for counts. It checks for the KG parameter followed by the disk unit and filename for the raw spread.

MASK2 calls subroutines MSUB, WEDGE, REF, and WLINE to do the bulk of the work in creating the output picture.

BAND

Purpose: To find the waveform and calculate Fourier coefficients for banded chromosomes.

Library Residence: Phase 14 of CALMS.OVR

The input to BAND is the rotated chromosome file, RCR. For each chromosome, BAND first decides if the chromosome is straight or bent.

For bent chromosomes, it curve fits a parabola to the boundary points and recalculates the chromosome length. The waveform is determined by sampling along the parabola, and using three points perpendicular to the slope of the parabola.

For straight chromosomes, the wave form is determined by sampling along each line, using a moving window of eight points. The maximum value found along the line is used.

A and B Fourier coefficients are then computed from the waveform values for eight harmonics. From these, C (amplitudes) and PHI (Phase Angle) are computed and saved in records 4-7 of the rotated chromosome file, RCR. Length and centromeric index are passed to FOUR as parameters.

BAND recognizes the following parameters:

WA Store a representation of the waveform in place of the rotated chromosome images.

AX Mark the axis for each chromosome

QB Quick BAND - process only the C group.

FOUR

Purpose: To classify banded chromosomes using Fourier coefficients, length, and centromeric index.

Library Residence: Phase 15 of CAIMS.OVR

The inputs to FOUR are the classification table of means and variances, and the banded chromosome measurements. FOUR computes the likelihood that each chromosome belongs to each of the chromosome types, using 14 measurements - length, centromeric index by area, C(2) to C(8), and PHI(2) to PHI(6).

If a chromosome's length or centromeric index differs by more than 6 S.D. for a particular chromosome type, that type is ruled out for that chromosome. Similarly, if the C sum or PHI sum exceeds 7 S.D. or the total sum exceeds 8 S.D., that type is excluded for that chromosome.

The chromosomes are then classified in order of likelihood, subject to group membership rules. This procedure may leave some chromosomes unclassified, since certain types may have been excluded for certain chromosomes.

Using the unclassified chromosomes, the most likely classification is found, say chromosome i belongs to group j. The chromosomes in group j are then examined to see if one of them can be moved to another group that is not yet full. If so, the most likely move is made.

The classification results are written as parameters for CLASFY.

PREP

Purpose: To print the patient report

Library Residence: Phase 16 of CAIMS·OVR

PREP reads the patient report records that were written on disk by RESEL, and prints them on the line printer. If the parameter PL is used, the records for different patients are separated by a double space. Otherwise, each patient's report is on a separate page.

ABNORM

Purpose: To print information on abnormal chromosomes

Library Residence: Phase 19 of CAIMS·OVR

ABNORM is called only when console switch 10 is down. It reads the rotated chromosome file, RCR, and examines the profile of each chromosome to determine centromere information. It then prints a message for each chromosome, regarding its normality.

KFIX

Purpose: Syntactical classification within B,D,F, and G groups.

Library Residence: Phase 20 of CALMS·OVR

KFIX is the final phase of the hybrid classifier for banded chromosomes, and operates as follows:

1) Take the 4 chromosomes in the G group. Measure the position along the length of the chromosome of the brightest band. The 2 chromosomes with the bright band closest to the center correspond to the G-21 the other two are the G-22.

2) Take the six chromosomes in the D group. Measure the ratio of average IOD in the upper half of the chromosome to that of the lower half of the chromosome. The two smallest values correspond to the D-13, the two largest values correspond to the D-15 and the remaining two are the D-14.

3) Separate the F-19 and F-20 chromosome by IOD. The two chromosomes with the smallest integrated optical density are the F-19's.

4) Take the B group. Measure the average IOD between the centromere position and a distance along the long arm equal to the short arm length or to the midpoint of the chromosome, whichever is shorter. The two chromosomes with the largest value correspond the B-4.

B. SYSTEMS SUBROUTINES

MVIO

Purpose: To read and write contiguous files with automatic double buffering, blocking, and random or sequential access to lines of data.

Library Residence: FTNLIB

Description: The calling sequences for the six entry points are as follows:

```
CALL OPEN(MVB,BUFSIZ,DBFLAG,MODE,LNAME)

CALL GET(MVB,LINE,INDEX[,NORA])

CALL PUT(MVB,LINE,INDEX)

CALL CLOSE(MVB)

CALL READ(MVB,LINE,INDEX,LOC)

CALL WRITE(MVB,LINE,LOC)
```

An OPEN call is required before any GET or PUT calls can be made to a dataset. The user must provide core space large enough to hold all the necessary control blocks and control information, as well as the data that is to be read or written. This allows MVIO to be re-entrant. In addition, no space is wasted on unused data sets, as would happen if MVIO contained storage for a fixed number of data sets.

The control information can be considered as a "mini-VICAR-block" or MVB. Each MVB is 56 bytes long and contains a tran block, link block, filename block and the information required by MVIO. (See Fig. 3-9).

The MVB is followed by one or two buffers to hold the data that is read or written. Each buffer is a multiple of the RK11 disk block size (512 bytes). An entire buffer is normally read from or written onto the disk with a single access. This greatly increases the effective transfer rate. When two buffers are provided, MVIO allows the user to overlap computation with the disk input/output.

GET and PUT are called to obtain the index relative to the start of the MVB for the desired record in the data set. Thus the data does not have to be moved from one buffer to another. On most "get" calls, the requested line will already be in one of the buffers and MVIO simply returns the index without any physical I/O required.

PUT is called to obtain the index of where to store the line that is to be written. MVIO initiates physical I/O when a buffer has been completely filled. A "close" call is required to write any data left in a buffer by ealier "put" calls.

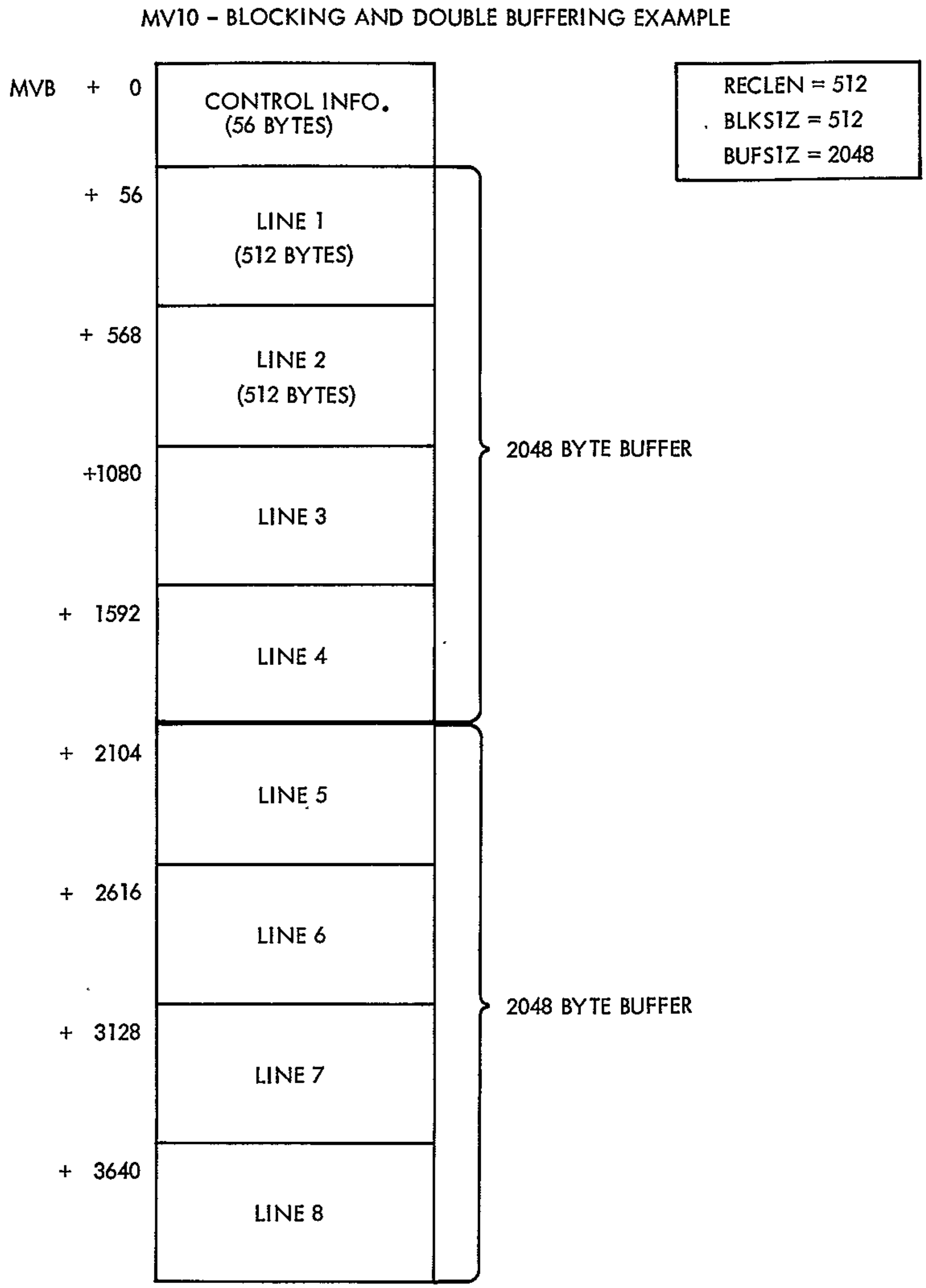


Figure 3-9 MV10 - Blocking and Double Buffering Example

A logical record (or line) can be smaller than, larger than, or the same size as the physical block size (512 bytes). As previously noted, each buffer is a multiple of 512 bytes in length, but the buffer must also be large enough to hold a complete logical record.

MVIO is normally used in conjunction with the label subroutines GLABEL and PLABEL, which are described in more detail elsewhere. They set up some of the fields in the MVB when the picture data is preceded by a label.

The fields in the calling sequences are defined as follows:

MVB is the location of the MVB for the data set. The user must reserve enough core for his buffers immediately following the MVB.

BUFSIZ is the size of each buffer (multiple of 512 bytes).

DBFLAG is the flag for double buffering, 0 = no double buffering (one buffer), 1 = double buffer (two buffers).

MODE is defined as:

0 = Disk Input	0, 1, and 2 are functionally
1 = Disk Output	equivalent
2 = Disk Update	
4 = Tape Input	4 and 5 are functionally
5 = Tape Output	equivalent

LNAME is a three character logical name for the data set that can be used to assign it to a file with the $AS command. (Subroutine AFILE can be used to make a default assignment).

LINE is the desired line number, positive for data lines, negative for label records, and zero for the "next" line.

INDEX is the offset in bytes from the start of the MVB to the requested line. In Fortran, when MVB is defined as a byte array, sample J of the requested line is at MVB(J+INDEX). In Macro, MVB+INDEX is the location of the first sample of the requested line.

INDEX is set to zero for an end-of-file read from tape.

NORA is an optional parameter to prevent read-ahead.

READ and WRITE can be used when RECLEN = BUFSIZ and single buffering is specified. A line is read into LOC, or written from LOC, without any overlap.

Updating is normally done with a GET and a PUT for the record to be updated. (The same index value will be returned on the GET and PUT.) This insures that other records in the block and other blocks in the buffer will not be changed.

MVIO
3

The "get" can be omitted only if all records are "put" sequentially, starting with the first record of a block.

The MVB format is shown below. Word numbers are in decimal, starting at 1 and byte numbers are in octal, starting at 0. TB = tran block, LB = link block, and FB = filename block.

WORD	BYTE		CONTENTS
1	0	TB	Active Block #
2	2	+2	Active Buffer Address
3	4	+4	Word Count
4	6	+6	Function/Status
5	10	+8	Words Not Transferred
6	12	IBN	Inactive Block #
7	14	IBA	Inactive Buffer Address
8	16	-2	Error Return
9	20	LB	Link Pointer
10	22	+2	Logical Name
11	24	+4	Unit # ! WordsTo Follow
12	26	+6	Device Name
13	30	CRC	Current Record #
14	32	-2	Indicator ! Unused
15	34	FB	File Name (Word 1)
16	36	+2	File Name (Word 2)
17	40	+4	Extension
18	42	+6	UIC
19	44	WNT	Words Not Transferred
20	46	SBN	Start Block #
21	50	NBF	# Blocks In The File
22	52	NLR	# Label Records
23	54	RECLEN	Record Length (Multiple or Divisor of BLKSIZ)
24	56	BLKSIZ	Block Size
25	60	BUFSIZ	Buffer Size (Multiple of BLKSIZ and RECLEN)
26	62	BPB	Blocks Per Buffer
27	64	DBF/MD	Mode ! Double Buffering Flag
28	66	WFLAG	Write Flag (Last Block # To Be Written + 1)

LABEL

Callable Entry Point Names: GLABEL, PLABEL

Purpose: To obtain and store label information on disk data sets.

Library Residence: FTNLIB

Description: These subroutines are used in conjunction with MVIO, when processing labeled data sets. They obtain or store the label parameters, and also set up the BLKSIZ, RECLEN, NLR, and BPB fields in the MVB. GLABEL and PLABEL must be called after the OPEN call for the MVB.

```
CALL GLABEL (MVB,SPAR,INDEX) to get a label
CALL PLABEL (MVB,SPAR,LABEL) to put a label
MVB is the mini-VICAR block for the data set.
SPAR is a five word table of system parameters

SPAR(1) = NL        #Lines of picture data
SPAR(2) = BPL       Bytes per line
SPAR(3) = BPE       Bits per element
SPAR(4) = NLR       # label records
SPAR(5) = BLKSIZ    Block size
```

GLABEL transfers the label information into SPAR.
PLABEL transfers the data in SPAR to the label.

Index is the offset from MVB to the first byte of the label, as returned by 'get'.

Label is the location of the label to be output.

Example:

```
INTEGER SPAR(5)
BYTE A(4200), B(4200)
CALL OPEN(A,2048,1,0,'MV1') Open A for input
CALL OPEN(B,2048,1,1,'MV2') Open B for outpu
CALL GLABEL(A,SPAR,IA)      Get label from A
CALL PLABEL(B,SPAR,A(IA+1)) Put label to B
```

GLABEL can also be used with an unlabeled data set. It will return NL as the # blocks in the data set

```
BPL = 512
BPE = 8
NLR = 0
```

These routines are re-entrant, except when GLABEL is used with an unlabeled data set.

EXIT

Purpose: To replace the FORTRAN exit and error subroutines and save 1260 bytes of core.

Library Residence: EXIT.OBJ [1,1]

Description: EXIT can be used to save core afcer a FORTRAN program has been checked out. ERRA gives a single error message (A367), instead of the individual messages normally given by the FORTRAN error routine ERRA.

When EXIT is called, it will either return to DOS via a .EXIT or return to CAIMS via an RTS R5. It makes this decision by checking the value of R5 when EXIT was called. When DOS loads a program, it clears R5, but when CAIMS loads a program, R5 is equal to a location within CAIMS.

Therefore, CALL EXIT will work for programs running under DOS or under CAIMS.

In order to select EXIT.OBJ over the FORTRAN exit subroutine, specify EXIT before FTNLIB in the link command string. The /SU switch should be used in the FORTRAN command string to save additional core and time.

All FORTRAN modules of CAIMS should be compiled with /SU or they may not fit in core.

SAVER

Purpose: To save and restore registers 0-4 on the stack, for subroutines called with an R5 calling sequence.

Library Residence: FTNLIB

Description: SAVER and RESTR provide a convenient way for MACRO subroutines to save and restore registers 0-4 on the stack.

To save registers 0-4:

```
JSR R4,SAVER
```

To restore registers 0-4 and return via R5:

```
JMP RESTR
```

Note that SAVER is called via R4, and that R5 is not saved.

AFILE

Purpose: To assign a file to a dataset

Library Residence: FTNLIB

Description:

```
CALL AFILE(MVB,DUNIT,FILPEX,GRP,USR)
```

MVB is the mini-VICAR block for the dataset.

DUNIT is the disk unit (1 for DK1:,2 for DK2:,etc.)

FILPEX is the 6 character filename plus 3 character extension

GRP is the group number from the UIC

USR is the user number from the UIC.

Example: CALL AFILE(A,1, 'PIC   , 5,5)

Assigns DK1:PIC[5,5] to MVB A

PARAM

Callable Entry Point Names: PARAM, PARBUF

Purpose: To read free-field parameters from the keyboard and convert them.

Library Residence: FTNLIB

Description: PARAM types an *, then reads up to 80 characters from the keyboard, terminated by a carriage return. Parameters are separated by blanks or commas, and can be one of the following:

1. One word integer - negative integers are preceded by a minus sign.

2. Two word alphameric - first character must be alphabetic. The character string is padded with trailing blanks if less than 4 characters. It is truncated if more than 4 characters.

3. Variable length alphameric - the string is enclosed in apostrophes. If an odd number of characters, the last word is padded with a trailing blank. If an apostrophe is desired, type two consecutive apostrophes.

The raw character string is saved at 'PARBUF' which is accessible to MACRO programs, but not FORTRAN. However, the user can optionally supply his own PARBUF.

The calling sequence is:

```
CALL PARAM(NP,PAR,MAXNP[,PARBUF])
```

NP is the number of parameter words that were stored in PAR

MAXNP is the maximum allowable number of parameter words (the size of PAR)

PARBUF is optional 83 byte user buffer for the raw character

Example:

```
INTEGER PAR(20)

CALL PARAM(NP,PAR,20)
```

If the user types:

```
NH,PRINT,42,-1,'ABC''DEF'
```

The result is:

```
PAR(1) = NH
   (2) = ΛΛ
   (3) = PR
   (4) = IN
   (5) = 42
   (6) = -1
   (7) = AB
   (8) = C'
   (9) = DE
  (10) = FΛ
```

NP = 10

PARAM is reentrant if the user supplies PARBUF. However, an earlier keyboard input request must be satisfied before a later one can be done.

PARAM maintains a byte with the global name 'PBUSY'. It is set to one when PARAM is entered, and cleared when PARAM exits.

Any program which is entered by an interrupt (such as SEARCH or HCOPY) must check that PBUSY = 0 before calling PARAM. If PBUSY is not zero, the program must signal PARAM that it is waiting to call it, but could not because PARAM was busy. It does this by storing the location for PARAM to transfer control to in 'PINT' or PINT+2, and then executing an RTI.

PARAM will then call the waiting routine with a simulated interrupt, when it has finished with the earlier request.

(The PBUSY, PINT method is required under DOS; otherwise the KB driver gets confused).

QPRINT

Purpose: To print a message, with automatic buffering

Library Residence: FTNLIB

Description: QPRINT waits for completion of a previous print, moves the message to its own buffer, initiates a print with a TRAN request, and returns to the user.

```
CALL QPRINT (LOC[,NBYTES])
```

LOC is the first byte to be printed (carriage control). NBYTES is the number of bytes to be printed. (Maximum = 132)
NBYTES can be omitted if the message is terminated with a "zero" byte. FORTRAN automatically inserts a zero byte for literal strings and 'ASCIZ', in MACRO, also does this.

Example:
```
CALL QPRINT(' single space')
CALL QPRINT('0 double space')
```

TYPE

Purpose: To type a message with automatic buffering

Library Residence: FPTNLIB

Description: Type is similar to QPRINT, except that output is on the keyboard and the maximum message length is 80 bytes.

```
CALL TYPE(LOC[,NBYTES])
```

If NBYTES is omitted or zero, a null (0) terminates the message. TYPE inserts a <CR> at the end of the message unless NBYTES = 0.

IV

Purpose: To convert and move logical*1 (byte) data and word data

Library Residence: FTNLIB

Description: IV is a function and the other entry points are subroutines. These routines consider bytes to be positive numbers from 0-255. (FORTRAN treats bytes as signed numbers from -128 to +127.)

IV(byte) = Integer value (0-255) of a byte variable

CALL ITL(INT,L1) (INTEGER to LOGICAL)
Move the low order byte of INT to L1.

CALL MVL(L1, L2, N) (Move LOGICAL)
Move N bytes starting at L1 to L2

CALL MVW(I1,I2,N) (Move WORD)
Move N WORDS starting at I1 to I2

CALL ZIA(IBUF,N) (Zero INTEGER array)
Zero N WORDS starting at IBUF

CALL ITLA(INT,L1,N) (INTEGER to LOGICAL array)
Store INT in N bytes starting at L1

CALL SWAP(I1,I2)
Interchange I1 and I2.

Note: RO is not saved by these routines!

TEXT

Purpose: To generate readable characters for labeling of pictorial output

Library Residence: FTNLIB

Description: Each character is generated from a six sample by seven line array of BIT , where a one BIT represents black and a zero bit represents white. The leftmost of the six samples is always zero.

```
CALL TEXT(INBUF,INCHR,LINE,OUTBUF,SIZE)
```

INBUF is the location of the input ASCII characters

INCHR is the # of input characters

LINE is the line number (0-6) of the bit array

OUTBUF is the location for the output bytes

SIZE is the number of bytes to store for each bit (1,2,...)

OUTBUF must be at least INCHR*SIZE*6 bytes long

HCPAK

Purpose: To pack and unpack data in hardcopy format (4 bits) and convert from 7 to 8 bit format.

Library Residence: FTNLIB

Description:

```
CALL HCPAK(BUF8 , BUF4 , NE)
CALL HCUPK(BUF4 , BUF8 , NE)
CALL MVW78(BUF7 , BUF8 , NW)
```

BUF8 is the LOC of 8-Bit Data
BUF4 is the LOC of 4-Bit Data
BUF7 is the LOC of 7-bit Data

NE is the number of elements to pack or unpack.NW is the number of words to convert from 7-Bit format to 8-Bit format.

RPARAM

Purpose: To pass parameters to a CALMS phase and to assign the next phase to be loaded

Library Residence: RPARAM.OBJ[2,2]

Description: CALL WPARAM(NP,PAR,PNUM)

NP is the number of words of parameters to write

PAR is the location of the parameters

PNUM is the number of the phase which is to receive the parameters

CALL RPARAM(NP,PAR,NPMAX[,PNUM])

To read parameters through the CALMS supervisor. See the PARAM writeup for details. PNUM is an optional phase number used to read another phase's parameters.

CALL APHASE(N)

Normally, phases are loaded in sequence, but APHASE is used to change the sequence.

N is the number of the phase.

DLINE

Purpose: Subroutines used to access the gray scale and cursor, when running under the CAIMS supervisor.

Library Residence: DLINE.OBJ [2,2]

CALL DCLEAR to erase the entire gray scale

CALL DLINE (LOC,Y,X,NS,REPL,ERASE) to write a line of data.
LOC is location of data in core.
Y is line on gray scale (0-1023)
X is starting sample on gray scale (0-1023)
NS is number of samples
REPL is non-zero to replicate samples and lines. (If switch 3 is up, only samples are replicated.)
ERASE is positive to erase this line before writing
negative to erase only
zero to write only.

CALL DWAIT to wait for gray scale ready

CALL CURSOR (Y,X,LINE,SAMP) to read the cursor.
Y is the line on the gray scale (0-1023)
X is the sample on the gray scale (0-1023)
LINE is the picture line (1-512)
SAMP is the picture sample (1-512)

CALL SC sets up the cursor adjustments and saves them on disk as parameters for INT1.

CALL RCA reads in the cursor adjustments from disk.

CALL MCU moves the cursor up one line

CALL MCD moves the cursor down one line

CALL MCL moves the cursor left one sample

CALL MCR moves the cursor right one sample

CALL UDLR(PAR) moves the cursor one step according to whether PAR is a U,D,L, or R.

The cursor adjustment process is required to correct for cursor drift. Two marks are written on the gray scale, one at 32,32 and one at 992,992. The operator is requested to move the cursor to these reference positions and the readings are saved. Thereafter, CURSOR performs a linear interpolation on all cursor readings, using the saved values.

There is also a standalone version of DLINE in FTNLIB. It differs from the CAIMS version in the way the cursor adjustments are saved and read back.

MCISUB

Purpose: Subroutines to control the MCI and sort the spread queue.

Library Residence: MCISUB.OBJ[2,2]

Description: This module consists of miscellaneous subroutines used by SEARCH and CALMS. It also globally defines the MCI register addresses and interrupt vector locations

CALL IXYABS(Y,Y)	Initiates a motor move to X,Y
CALL IXREL(XDEL)	Initiates a relative X move
CALL IYREL(YDEL)	Initiates a relative Y move
CALL IFREL(FDEL)	Initiates a relative F move
CALL CFOC(F)	Stores the sum of the two focus parameters
CALL LED (CODE,VAL)	Puts VAL in the LED whose code is given
CALL MFST (MAGN,FPOS)	Stores the magnification and filter position in MAGN and FPOS, and displays the magnification in the magnification LED. It also stores FSTEP, FLAST, XADJ, and YADJ for the lens in use.
CALL SORTQ	Sorts the spread queue according to its ratings

ROACH

FUNCTION: ROACH(WI,BI,WORD,EWI,MASK)

LIBRARY RESIDENCE: GMYLIB

ROACH will scan a binary line to locate the first set bit. The scan will begin at WORD(WI) and end at WORD(EWI). If no set bit is found, the return code is zero. If a set bit is found, WI is returned as the index of the word containing the bit. BI is the bit index within the word (numbered 0,1,2,...,15). The corresponding bit position within the MASK is also set.

TURTLE

LIBRARY RESIDENCE: GMYLIB

TURTLE is invoked by SEGMNT to walk counterclockwise around the perimeter of objects in the binary picture.

```
CALL TURTLE(COMMON,EDGE,WORD,MASK,NW2)
```

COMMON is composed of the following six words:

N	=	the number of segment end points found
PERIM	=	the number of perimeter points found
YMIN,XMIN,YMAX,XMAX	=	the extreme coordinates of the object

EDGE is an integer array into which is placed the coordinates of the detected end points. On input, WORD points to the word containing the first detected bit of the object and MASK designates the bit positions within that word. NW2 is the number of bytes per line.

The TURTLE uses a four point connectivity algorithm in walking around the perimeter. At each step, the TURTLE will examine its four adjacent neighbors, numbered 0, 1, 2, and 3 (Fig. 3-10) to determine its new direction. The order in which neighboring samples are examined is predetermined to ensure that the TURTLE will always proceed in a counterclockwise direction (Fig. 3-11).

Since not all perimeter points are segment end points, the TURTLE uses a decision table to identify the end points. End point determination is based on the TURTLE's previous and current directions, and his conviction that since he is traversing the perimeter in a counterclockwise direction, the chromosome will always remain on his left. Line segments which contain only one sample are recorded twice so that all segments have starting and ending end point coordinates. The TURTLE's decision table is given in Fig. 3-10. The number of times perimeter points are recorded as end point coordinates appears in parentheses.

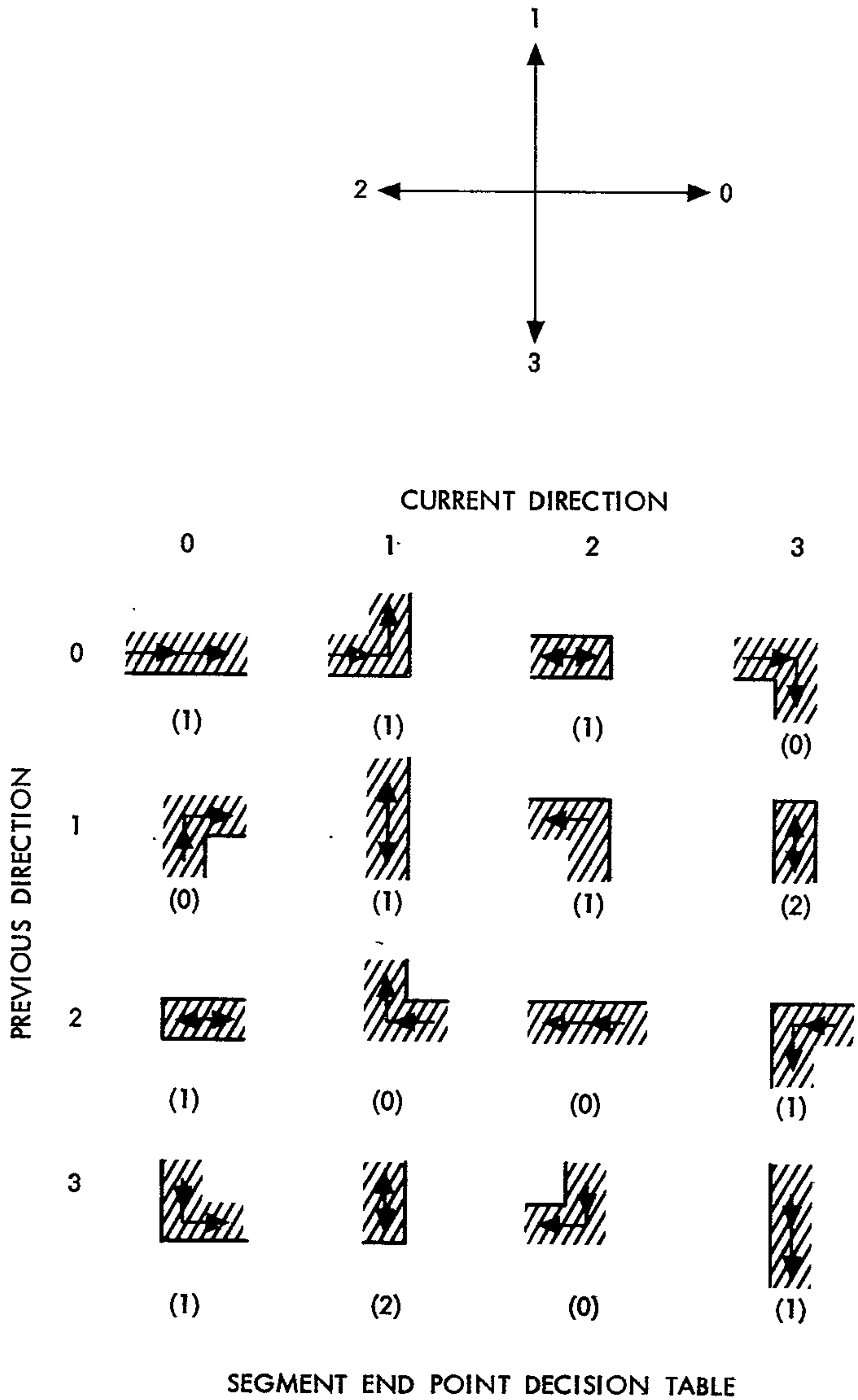


Figure 3-10 Segment and Point Decision Table

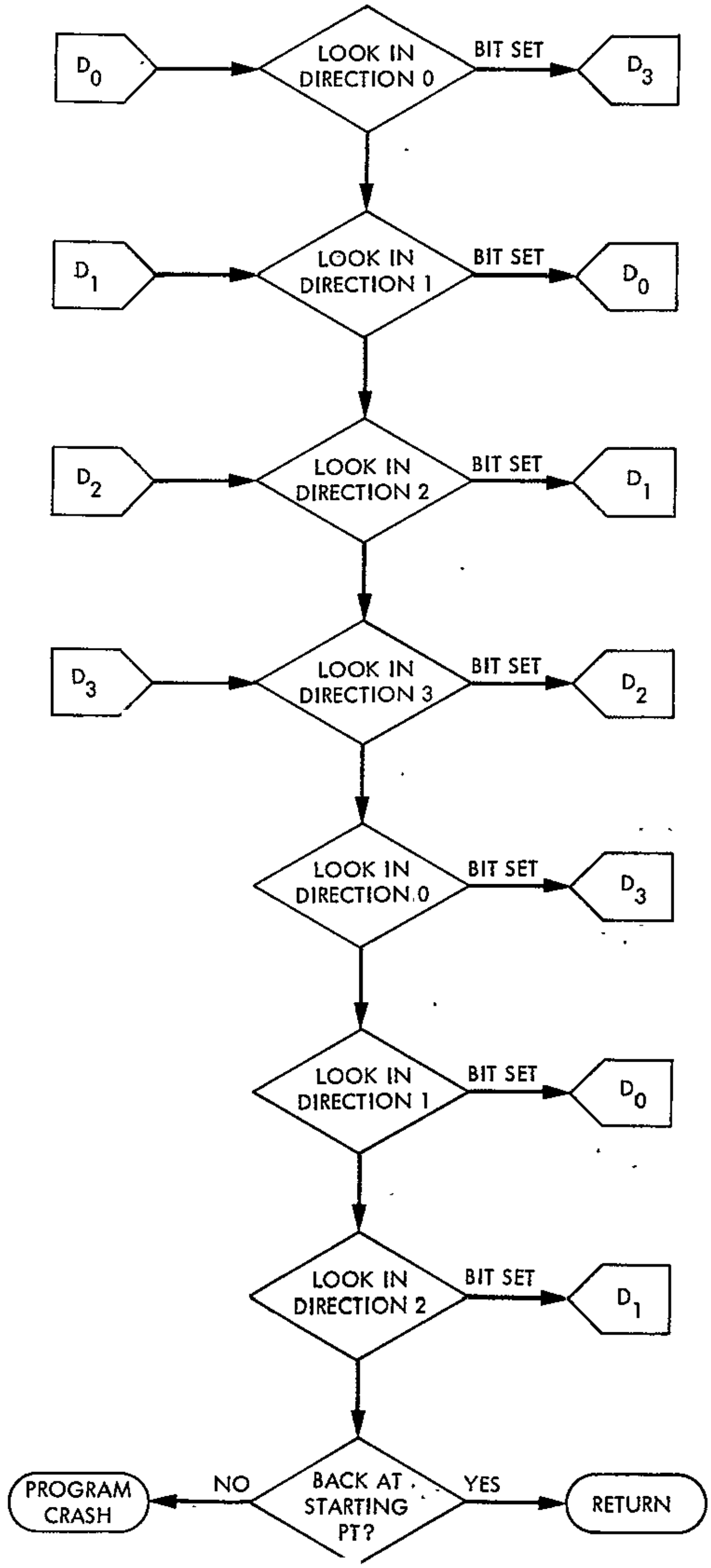


Figure 3-11 Four Point Connectivity Algorithm

SORTIN

LIBRARY RESIDENCE: GMYLIB

SORTIN is invoked by SEGMNT to sort the end point coordinates for a chromosome in the order that they would be encountered while scanning the chromosome line-by-line from left to right. Thus, the sort is in ascending order, first by line coordinate, and second by sample coordinate.

```
CALL SORTIN(EDGE,N,IND)
```

N is the number of end points.

Upon return, IND=0 if the sort was successful, ≠0 if not.

EDGE is a buffer area 4N words long. The first 2N words contain the end point coordinates for the chromosome. The remaining 2N words is used as a work area for the bucket sort routine.

SORTIN uses a byte array to keep track of the ordering of the end points. Because of this, a maximum of 255 end points may be sorted.

ERASE

LIBRARY RESIDENCE: GMYLIB

ERASE is invoked by SEGMNT to remove a chromosome from the binary spread image.

```
CALL ERASE(WORD,EDGE,AREA,N2,NW)
```

WORD points to the buffer area containing the binary image.

EDGE points to the end point coordinates for the chromosome

N2 is the number of coordinates in EDGE (two per coordinate pair).

NW is the number of words per line in the binary image.

AREA is returned as the number of sample points contained in the chromosome.

ORIOB

Purpose: Orient objects.

Library Residence: GAJLIB

Description:

CALL ORIOB(IBUF,OBUF,EP,CHDIR,NL,OPROT,RCODE)

ORIOB finds the minimum enclosing rectangle for the object in IBUF using the endpoint table EP and 32 rotations from 0 to 90 degrees. It then rotates the object into OBUF and sets the rotated NL and NS in CHDIR. OPROT specifies any additional rotation desired by the operator.

EPROT

Purpose: Rotates chromosome endpoints.

Library Residence: GAJLIB

Description:

CALL EPROT(SIN,COS,NL,EP,XMIN,XMAX,YMIN,YMAX)

EPROT rotates the endpoints (EP) by the angle specified by SIN and COS. It returns the limits of the enclosing rectangle (XMIN,XMAX, YMIN,YMAX).

OBRO'

Purpose: To rotate objects.

Library Residence: GAJLIB

Description:

CALL OBROT(XMIN,XMAX,YMIN,YMAX,COS,SIN,IBUF,OBUF)

OBROT rotates the object in IBUF into OBUF. COS and SIN specify the rotation angle and XMIN,XMAX,YMIN,YMAX give the enclosing rectangle of the object in unrotated coordinates.

Four point linear interpolation is used to set the intensity values of the rotated object.

ACCSUB

Purpose: Accumulate area and density by sample for rotated object.

Library Residence: GAJLIB

Description:

```
CALL ACCSUB(BUF,NL,NS,AREAA,DENA,TAREA,TDEN)
```

The chromosome is located in BUF and is NL by NS. AREAA is the area accumulator by sample and DENA is the density by sample. TAREA and TDEN are the area and density totals for the object.

CHROUT

Purpose: To stand objects up and move them into the output buffer.

Library Residence: GAJLIB

Description:

```
CALL CHROUT(IBUF,OBUF,NS,NL,LPB,IP,FLG,BUFSZ)
```

CHROUT rotates the object in IBUF (NS X NL) by ±90° into OBUF for output. LPB gives # of lines that will fit into OBUF, FLG tells which way to rotate object and BUFSZ is NS for IBUF.

KURSOR

Purpose: To locate information about the karyogram from the current cursor position.

Library Residence: KURSOR.OBJ

Description:

```
CALL KURSOR(Y,X,L,S,SLID,SLCL,SLCS,N)
```

Y,X,L,S are the cursor coordinates returned by cursor. SLID is the slot ID indicated; SLCL and SLCS are the slot center coordinates; and N is the object ID of the object residing in the slot.

C. STATISTICS AND MAINTENANCE PROGRAMS

CSTAT (Chromosome Statistics)

CSTAT will calculate the statistics of various measurements for specified spreads of chromosomes. It is an interactive program executable from the typewriter.

1. INPUT OPTION

MEASUREMENTS

(1) LE length
(2) IØ IØD
(3) AR Area
(4) CL Centrometric index by length
(5) CD Centrometric index by IOD
(6) CA Centrometric index by area
(7) FO Fourier coefficients
(8) CV Covariences of 2 measurements
(9) DI Directory
(10) BC Updates the banded classifier

SPREADS

(1) All spreads from one or multiple sources of conventional or banded files (max, 20)

(2) Single or multiple spreads by record numbers (max, 100)

(3) Single patient (all cells)

(4) Excluding record numbers for item (1)

2. EXECUTION and ERROR MESSAGES

(1) ENTER SOURCE

1. Positive source number(s) for conventional source.

2. Negative source number(s) for banded source.

- ERROR IN SOURCE NUMBER XX CHECK AND RETYPE

- If source(s) are going to be the input then CR for following (3) and (4)

(2) ENTER MEASUREMENTS

1. CR for all measurements (LENG, IØD, AREA, CIL, CID, CIA and FOUR for banded)

2. DESIRED MEASUREMENTS

   One or multiple of above listed measurements.

   Keywords are LE, IO, AR, CL, CD, CA, FØ

3. COVARIENCES

   Keyword CV followed by measurement (1) and measurement (2).

4. DIRECTORY

   Keyword is DI

5. UPDATE BANDED CLASSIFIER. Keyword BC

   · ERROR IN MEASUREMENT, RETYPE

(3) ENTER RECORD NUMBER

1 CR if none

2 Desired patient's record number (max, 100)
If line gets full, CR and wait for next message. Then continue on

RECORD XXX is beyond last record.

CHECK AND RETYPE RECORDS

(4) ENTER PATIENT'S ID

1 CR if none

2 Desired single patient's ID

· NO DATA FOR THIS SOURCE. CHECK AND RETYPE SOURCE.

· NO PATIENT ID XXXXXXXXX CHECK AND RETYPE

(5) TYPE RECORDS TO BE EXCLUDED

1 CR if none

2 Type record numbers to be excluded until end of line. CR, wait for next command and continue typing.

· This command applies for (1) above.

*If record line is empty (might be deleted) it will type NO DATA IN RECORD XXX and continue on.

*All the replies end with carriage return

*Each item will be separated by a comma.

SPLOT (Scattergram Plot)

SPLOT will produce a 2-dimensional line printer plot (or scattergram) of centrometric index versus size for selected spreads which are specified

1. SCALE Options

   Horizontal scale is normalized size measurements and the vertical scale is centrometric index. Horizontal scale can be single LENGTH, IØD or AREA. Centrometric index can be computed by length area or IØD.

   Combinations of measurements can be used with varying percentages as weighting factors.

2. INPUT Options

   (1) All spreads from one source of conventional or banded files.

   (2) Multiple sources of same kind (max, 20)

   (3) Multiple spreads by record numbers (max, 100)

   (4) Single spread by record number.

   (5) Single patient, all cells

   (6) Excluding record numbers for item (1), (2)

3. EXECUTION

   SPLOT is an interactive program executable from the typewriter.

   The order of inputing and its explanations for responding follows. All the responses should end with CR, carriage return. A comma should follow each item.

   (1) ENTER SOURCE

      1. Positive source numbers for conventional source.

      2. Negative source numbers for banded source.

         - If no source file can be found, error message will ask to check and retype

         - If all spreads in sources are to be worked on then CR for (2) and (3) following.

(2) ENTER RECORD NUMBERS

1. CR, if not entering by record numbers.
2. Desired single or multiple record numbers. If line gets full before finishing, CR and wait for next command and continue on. (MAX = 100)
   - If a record number is beyond the last record, it will ask to check and retype all the numbers again.
   - If there are no data in certain record, it will type the record number and continue on.

- Next command will be for measurements. (5)

(3) ENTER PATIENT'S ID

1. CR, if not entering by patient ID
2. Desired single patient ID
   - If it can't find the patients data it will ask you to check the patients ID and retype.

- Next command will be for measurements (5)

(4) TYPE RECORDS TO BE EXCLUDED

This applies when you are working on whole source and want to ignore certain records.

1. Type the record numbers you want to be excluded from the entire source
   - Error messages are same as (2)

(5) ENTER MEASUREMENTS FOLLOWED BY PERCENTAGES

1. For sizes LE, IO, AR (LENG, IOD, AREA), for centromere CL, CD, CA (CIL, CID, CIA). Each measurement is followed by a percentage. Multiple sizes can be used with different percentages adding up to 100.

EXAMPLE

```
LE, 100, CL, 100
LE, 50, IO, 30, AR, 20, CL, 50, CA, 50
```

Error message will be typed when measurements are incorrectly entered.

(6) LIST TYPES

1. Type in the numeral part of the chromosome type. X is type 23 and Y is type 24.

   One or more types can be entered.

2. CR if all type is desired.

4. EXPLANATION OF THE SCATTERGRAM

(1) When single spread input is used with all types, the object numbers will be plotted.

(2) When specific types are requested, the number of occurrences at each position is printed at that position.

(3) When all types are requested, the following letters are printed on the position. 1, 2, 3 for A-1 through A-3, B for B group, C for all C group and X, D for all D group, 6 for E-16, E for E-17, 18, F for all F group, G for all G group and Y chromosome. It is not able to show more than 2 overlaps at one position.

RPRINT

Purpose: To print the banded classification table

Library Residence: RPRINT·LDA[1,1]

RPRINT prints the means and variances of all the measurements for each chromosome type in the banded classification table. The table is stored in DK4:CDATA[6,6]in the following format:

Record 1 contains MU(18,24) followed by SIGMA(18,24), both REAL*4. MU contains the mean values and SIGMA contains the variances for the 18 measurements and 24 chromosome types. The first "measurement" in MU is the number of chromosomes for this type. The first measurement in SIGMA is reserved for the covariance of length and centromeric index, but is currently unusued.

The record length is 3584 bytes with 3456 bytes of data.

The 18 measurements are stored as follows:

Word (4 bytes)	
1	NCHR (in MU) unused in SIGMA
2	LENGTH (normalized in range 0-500)
3	CIA (in range 50-99)
4-11	CFOUR(1) - CFOUR(8)
12-18	PHI(2) - PHI(8)

The classifier currently doesn't use all of these measurements, but they are available for future use. PHI(1) is always zero, and is not saved here. It should be noted that file RCR does contain PHI(1), however,

The Fourier coefficients for a spread are saved in records 4-7 of file RCR, which has a record length of 1024. The spread measurements are stored in:

```
REAL*Y 4 CFOUR(60,8)
REAL*Y 4  PHI (60,8)
Record 4 contains 960 bytes starting at CFOUR(1,1)
  "    5     "      "    "     "      "   "  (1,5)
  "    6     "      "    "     "      "  PHI (1,1)
  "    7     "      "    "     "      "      (1,5)
```

RPRINT

Purpose: To print the banded classification table

Library Residence: RPRINT•LDA[1,1]

RPRINT prints the means and variances of all the measurements for each chromosome type in the banded classification table. The table is stored in DK4:CDATA[6,6] in the following format:

Record 1 contains MU(18,24) followed by SIGMA(18,24), both REAL*4. MU contains the mean values and SIGMA contains the variances for the 18 measurements and 24 chromosome types. The first "measurement" in MU is the number of chromosomes for this type. The first measurement in SIGMA is reserved for the covariance of length and centromeric index, but is currently unusued.

The record length is 3584 bytes with 3456 bytes of data.

The 18 measurements are stored as follows:

<u>Word (4 bytes)</u>

1	NCHR (in MU) unused in SIGMA
2	LENGTH (normalized in range 0-500)
3	CIA (in range 50-99)
4-11	CFOUR(1) - CFOUR(8)
12-18	PHI(2) - PHI(8)

The classifier currently doesn't use all of these measurements, but they are available for future use. PHI(1) is always zero, and is not saved here. It should be noted that file RCR does contain PHI(1), however,

The Fourier coefficients for a spread are saved in records 4-7 of file RCR, which has a record length of 1024. The spread measurements are stored in:

```
REAL*Y   CFOUR(60,8)
REAL*Y    PHI (60,8)
Record 4 contains 960 bytes starting at CFOUR(1,1)
  "    5    "    "    "    "    "   " (1,5)
  "    6    "    "    "    "    "  PHI (1,1)
  "    7    "    "    "    "    "      (1,5)
```

DON

Purpose: To delete object numbers of atypical chromosomes from the measurement file.

Library Residence: DON·LDA[1,1]

DON is normally run on spreads that are to be added to the banded classifier table. It allows the user to delete non-representative chromosomes from the measurement file, KRM. The default assignment is DK4:BDATA[6,6], for banded spreads and DK4:KDATA[6,6] for conventional spreads.

The source, record number, and object numbers are entered interactively from the keyboard.

DREC

Purpose: To delete a record from KDATA or BDATA

Library Residence: DREC·LDA[1,1]

DREC operates interactively with the user at the typewriter. Enter the source and record numbers to be deleted. DREC sets the patient ID field in the directory record to zero, but leaves the record number field unchanged. RESEL checks for this condition and is able to re-use the deleted record.

GS

Purpose: To exercise the gray scale display and cursor

Library Residence: GS.LDA [1,1]

Description: GS can be used to display a picture from disk, display a generated grid or bar picture, read the cursor coordinates and display them, or loop under switch 0 control for diagnostic purposes.

The options are selected by parameter keywords. The default is to display a picture from disk.

The keywords are:

GR - Display a grid picture, 512 x 512 with 8 x 8 grids
V1 - Display 17 vertical bars white - black - white
V2 - Display 17 vertical bars black - white - black
H1 - Display 17 horizontal bars white - black - white
H2 - Display 17 horizontal bars black - white - black
RC - Diagnostic write; issue a gray scale RESET, write a line of 1024 zeroes (white) at line 0 of the gray scale, wait 20 ms. and loop back if SWO is up.
DE - Diagnostic erase; issue a gray scale RESET, erase line 0 of the gray scale, wait 20 ms. and loop back if SWO is up.
EW - Diagnostic erase/write; same as DW but erase/write command is issued.
DC - Diagnostic clear; issue clear command and loop back if SWO is up

If no keyword (or any other keyword) is typed, the picture on disk dataset MV1 is displayed. The default assignment is DK1:PIC[5,5]

When SW1 is up, the displayed picture is replicated.

The GRID picture occupies 1024 x 1024 and the bar picture occupies 1020 x 1020.

The entire screen is cleared before each display.

HCOPY

Purpose: To output a picture on the HARDCOPY unit

Library Residence: HCOPY·LDA[1,1]

Description: The input picture is MSK defaulted to DK5:PIC[5,5]. The picture can be packed (MASK output) or unpacked. Console switch 1 up causes replication of lines and samples.

The maximum elements per line is 1016 in packed mode and 1014 in unpacked mode.

D. UTILITY PROGRAMS

ADDON — Position tape after last data file and print # files currently on the tape. INPUT = TAP, DEFAULT = MTO: (Do not use if tape is blank).

DISP — Display a picture on the line printer.
INPUT = MV1 DEFAULT = DK1:PIC[5,5]

Parameters

CO — Complement the character table, normally, 0 = white, CO causes 0 = black.

NO — NONUM Suppress line and sample numbers on the displayed picture.

LI,N — LINE INCREMENT = N DEFAULT N = 5
Display every Nth line.

SI,N — SAMPLE INCREMENT = N DEFAULT N = 4
Display every Nth sample.

SL,SS,NL,NS — Four numbers - the starting line, starting sample, # lines, # samples that describe the area of the picture to be displayed. These must be the last parameters.

DEFAULT: 1, 1, NL, NS (entire picture)

If switch 0 is up, the default is NO,LI,1,SI,1

A maximum of 128 samples can be displayed on one page. Extra passes through the picture are made, when required.

DCOPY — Copy disk DKA to disk DKB
Default is DKO: to DK2:
DCOPY transfers the entire disk.

DTD — DISK to DISK transfer of one dataset
INPUT = MV1 DEFAULT = DK5:PIC[5,5]
OUTPUT = MV2 DEFAULT = DK1:PIC[5,5]

DTD copies the input picture into the output picture, using input picture label to get the size. One extra line is copied for threshold records on scan datasets.

LIST — Print the gray levels of an area of a picture and/or produce a line printer histogram

INPUT = MV1 DEFAULT = DK1:PIC[5,5]

The Parameters are:

SX — Convert the data from seven or eight bits to six bits. Print 40 elements per page.

EI — Eight bit data. Print 30 elements per page. This is the default.

HA — Halfword data. (Two bytes per element) Print 24 elements per page.

LI,N — Line Increment = N DEFAULT:N = 1 Print every Nth line.

SI,N — Sample Increment = N DEFAULT:N = 1. Print every Nth sample.

NP — No print.

NH — No histogram.

PR — Print (DEFAULT)

HI — Histogram. (DEFAULT)

SL,SS,NL,NS — Four numbers - starting line, starting sample, # lines, # samples - that describe the area of the picture. These must be the last parameters.
DEFAULT: 1, 1, NL, NS (Entire picture)

When finished, LIST looks for a new set of parameters at the keyboard. Old parameters remain in effect until cancelled.

The average gray level and standard deviation are always printed, even if both NP and NH are specified.

LISTIO — List current I/O assignments

All current assignments (made by AS) are listed. At present, when a logical name is reassigned, all assignments disappear when the current program finishes.

When reassigning, the best procedure is to type AS with no operands to clear all assignments. Then, enter the new assignments.

DTT DISK to TAPE transfer

INPUT = MV1 DEFAULT = DK1:PIC[5,5]
OUTPUT = TAP DEFAULT = MTO:

The output tape should be correctly positioned, before running DTT.

In the absence of parameters, the disk label will be copied onto the tape and an unblocked tape will be written.

Allowable Parameters are:

NO NOLAB do not write a label

BL,N BLKSIZ = N The tape blocks will be N bytes long.
DEFAULT: BLKSIZ = BPL from label. BLKSIZ should be a multip__ of BPL.

TR Write a threshold record (required for scan datasets).

DUD DISK UPDATE
DISK Logical name = DSK. DEFAULT = DKO:
DUD is used to modify the contents of a disk block. It prints the core location which is to contain the disk block number and pauses. Use "MO" to insert the desired block number and "CO" to continue. DUD then reads the block into core starting at location 20,000, and pauses again. Modify core and continue, to update the disk block.

GEN Generate a picture.

OUTPUT = MV1 DEFAULT = DK1:PIC[5,5]

The Parameters ~~are~~:

NL,NS,IV,HI,VI (five numbers)

NL is the number of lines, and NS the number of samples on each line.

IV is the initial value, HI the horizontal increment, and VI the vertical increment, and VI the vertical increment

E.G. 200, 512, 11, 1, 10 will generate a picture of 200 lines, with 512 samples per line.

The intensity values in the upper left corner will be:

11, 12, 13, . . .
21, 22, 23, . . .
. . .
All values are mod 256.

MASK Add border to a picture

```
INPUT = MV1       DEFAULT:  DK1: PIC[5,5]
OUTPUT = MSK      DEFAULT:  DK5: PIC[5,5]
```

MASK adds a gray scale, reference marks, annotation, and an optional histogram to an area of a picture.

Allowable Parameters are:

HI	a histogram of 200 lines is produced.
HS,N	a histogram of N lines is produced.
SL,SS,NL,NS	four numbers - starting line, starting sample, # lines, # samples - that describe the area of the picture. These must be the last parameters. Default is entire picture.

The MASK output is in packed format (BPE = 4).

The minimum # samples is 360, to accomodate the date and time label that is produced. The maximum # samples is 1000. The # samples will be forced into this range. The output picture has 24 more samples than the input picture and many more lines.

QSCAN Quick Scan for Printer Display

QSCAN is similar to SCAN, but it scans only the elements required for a printer display. The picture is saved in core and printed when the scan is complete. Entries to print another copy or save the picture on tape or disk are also provided.

TAPE output = TAP		DEFAULT:	MTO:
DISK output = MV1		DEFAULT:	DK1:PIC[5,5]

Either a label, one of the keywords LP, MT, or DK, or a carriage return may be entered as a parameter.

The label is typed without bracketing apostrophes and causes a scan plus a printer display. The picture will be framed and up to 13 characters of the label will be printed beneath it.

A carriage return causes a re-scan with the current label.

LP causes another print of the current picture
MT transfers the picture to tape
DK transfers the picture to disk

RT Rewind tape
RT rewinds 'TAP' DEFAULT = MTO:

SAVE Save disk on tape in bootable format.

Save writes an entire disk on tape in 6144 byte blocks. A bootstrap is written first, then 400 blocks, then an end-of-file.

The disk assigned to DSK is saved. DEFAULT - DKO:
SAVE puts the unit number in the bootstrap, so the same disk will be restored when the tape is booted.

When restoring the disk, several halts can occur.

150 Normal halt after disk is restored. Press continue to boot in the disk (if DKO was restored).

60 Tape error. Press continue to try again.

212 Disk error. Press continue to try again.

Since several disks can be saved on one tape, an entry to forward space a file is included. Start at location 224 to advance 1 file. A halt at 254 will occur. If another file is to be skipped, start again at 224. If you have reached the desired file, press continue to boot in the next file on tape.

SCAN — Scan a picture from the data camera onto disk, with gray scale display

DISK output = MV1 DEFAULT: DK1:PIC[5,5]

STR — Stretch the intensity values of a picture and/or change its size.

INPUT = MV1 DEFAULT: DK1:PIC[5,5]
OUTPUT = MV2 DEFAULT: DK5:PIC[5,5]

The Parameters are:

SZ,SL,SS,NL,NS — SL,SS,NL,NS are four numbers which describe the starting point and size of the output picture. DEFAULT = entire picture

LI,NMIN,NMAX — Perform linear stretch between NMIN and NMAX

TA,X1,Y1,X2,Y2,. . .,XN,YN — Perform a table stretch. X represents an input value and Y the corresponding output value. Both X and Y are fixed point numbers.

CL,NBIT — CLIP NBIT bits from the picture.

If no parameters are specified, or if SZ is the only parameter, the input values will be copied unchanged to the output picture.

TTD — Tape to Disk Transfer

INPUT = TAP DEFAULT MTO:
OUTPUT = MV1 DEFAULT DK1:PIC[5,5]

TTD transfers a tape file to disk. The user specifies the file number and TTD positions the tape before transferring the file to disk. (The current file is maintained by subroutines MT and MVIO).

TTD can also be used to list the contents of a tape.

If the tape has an 1140 system label, TTD will transfer the label to disk. Otherwise, it creates a label. TTD uses the length of the first data block, and the number of blocks in the file to create the label.

The Allowable Parameters are:

FI,N — File N is the desired file. (The first file is 1.) N=0 means get the next file on the tape and is the default. If this is the only parameter, FI can be omitted.

PO — position the tape, but do not transfer the file to disk.

BP,N — BPL=N Use this parameter with blocked unlabeled tapes to specify the bytes per line of a logical record.

NO — No label on this tape. This parameter is required when the first word of the first block could be confused with the label code word (1140). Otherwise, TTD can determine that there is no label.

VI — The tape has a VICAR label. The tape will be treated as though it were unlabeled, but the first block (the VICAR label) will be ignored.

LI,TID — List the contents of tape 'TID.' TID is 4 characters or less. The size and first 30 characters of the first two labels will be listed for all files on the tape.

SL,N — Starting line for data transfer is line N. This is normally used with long files on unlabeled tapes.

NL,N — The number of lines to transfer is N. This is normally used when the tape file is too large for the disk data set.

TR — The last line on tape is a threshold record.

<u>UPLAB</u> — Update label
DISK data set = MV1 DEFAULT: DK1:PIC[5,5]

The entire label is listed. Then, the user can add a new label or replace all labels with a new label.

To all a label, type 'LABEL TO BE ADDED'
To replace all labels, type RE, 'NEW LABEL'
To leave the labels alone, type a carriage return.

MTDGN

Purpose: Put diagnostics on mag tape and load them from mag tape

Description: The program occupies locations 156000 - 156203. The absolute loader is read in to location 157500 and above. A diagnostic is read by the absolute loader into locations 0-16K.

Starting at 156,000, with a tape at load point, the program writes 2 bootstrap blocks, a block that the bootstrap reads into 156,000-157777, and a block from 0-16K. (The first diagnostic). A halt at 156132 should occur.

Read in the next diagnostic and start at 156070 to write it on tape and halt at 156132. Continue until all diagnostics are written. Label the tape with the names of the diagnostic and their sequence #s. The first diagnostic is 0, continue in OCTAL 1,2,3,4,5,6,7,10,11...

To read in a diagnostic, bootstrap in the tape. It will read itself and the first diagnostic into CORE and halt at 156132.

If a diagnostic other than the first is desired, put the sequence # in the console switches and press continue. The desired diagnostic will be read in and program halts at 156132.

After running the diagnostic, if you want to read in another one, rewind the tape and re-boot.

To add a new diagnostic, read in the last diagnostic on the tape, read in the new diagnostic (with the paper tape loader at 157500) and start at 156070.

Error halts can occur as follows:

156036 - Error in writing tape bootstrap
156070 - Error in writing MTDGN on tape
156126 - Error in reading or writing a diagnostic
173260 - Error in reading tape bootstrap
40 - Error in reading first diagnostic on tape

The normal halt is 156132.

E. SYSTEM PROGRAMMER'S INFORMATION ON CALMS DATA SETS

CAIMS runs under the DOS-BATCH monitor, which allows for monitor commands from the keyboard or from a batch dataset. Batch datasets are especially convenient for running LINK, and each phase of CAIMS has a batch dataset to build it, after its object modules are created by FORTRAN or MACRO. The batch datasets are created and modified by EDIT.

The CAIMS programs are stored under user identification code [2,2]. Some of the subroutines used by these programs are stored under UIC [5,5], [13,13], and [44,44]. The statistical programs are stored under UIC [6,6]. When appropriate, load modules are saved in UIC[1,1], so they can be called with the $R command.

The resident portion of CAIMS is created by the batch dataset BCAIMS. This creates CAIMS.LDA[2,2]. The dataset SCAIMS saves CAIMS in UIC[1,1].

The major components of CAIMS have fixed amounts of core reserved for them. This allows changes to be made to one component without having to re-LINK all other components.

The following table gives the names of the batch datasets used to build each phase of CAIMS:

1 - BSCAN	10 - BKTYPE
2 - BBIN	11 - BINT2
3 - BSKRT	12 - BRESEL
4 - BCHRM	13 - BMASK2
5 - BROB	14 - BBAND
6 - BNOB	15 - BFOUR
7 - BINT1	16 - BPREP
8 - BMOB	19 - BABNRM
9 - BCLASF	20 - BKFIX

If it is ever necessary to rebuild the entire system, the dataset BBSYS creates a new batch dataset called BSYS. Then, BSYS is used to build the entire system.

The banded classifier table, CDATA, is built with the dataset BBC, which contains a list of record numbers in BDATA that are to be used.

DK4:BDATA[6,6] and DK4:KDATA[6,6] are the statistical datasets used to store banded and conventional measurements. KDATA has 500 records of 1024 bytes, and will hold 500 conventional spreads. BDATA has 1000 records of 1024 bytes and will hold 250 banded spreads.

Each time a spread is processed, its record number in KDATA or BDATA is typed out. When the data sets are almost full, they should be saved on tape with the batch dataset SSTAT. The batch datasets ZBDATA and ZKDATA will zero BDATA and KDATA.

In order to save time, a table of disk block numbers for commonly used datasets is stored on block 0 of DK1:. MVIO reads this table into core, and saves the time of reading the disk directory records when one of these datasets is opened. These datasets should not need to be re-allocated, but if they are, the batch dataset BVAT must be used to build the assignment table with the new disk block numbers.

The datasets in the table are:

```
DK1:PIC[5,5]
DK5:PIC[5,5]
DK5:SN[2,2]     N=1,3
DK5:UCR[13,13]
DK1:RCR[13,13]
DK3:HN[2,2]     N=1,2
DK4:PDATA[6,6]
DK4:KDATA[6,6]
DK4:BDATA[6,6]
DK4:CDATA[6,6]
DK5:CALMS.OVR[2,2]
DK5:CALMS.PAR[2,2]
DK3:PIC[5,5]
```

OVB

Purpose: Overlay builder for CALMS supervisor.

Library Residence: OVB.LDA [1,1]

Description:

The input data set should contain a contiguous load module output by LINK The output data set is an overlay data set.

OVB requests a parameter from the keyboard; the phase number, N. It then writes the phase as record N in the output data set. The output data set has a record length of 32,256 bytes, and no label records.

The default assignments are:

Input - DK5:PHASE.LDA[2,2]

Output - DK5:CALMS.OVR[2,2]

SECTION IV

MOTOR CONTROL INTERFACE

A. SYSTEM DESCRIPTION

The Motor Control Interface (MCI) is a JPL designed and built digital logic unit whose functions are:

a) To control the positioning of the microscope specimen stage by command from both the computer and the system operator.

b) To provide the interface to the computer for the Spread and Focus data words.

c) To provide the control and computer interface logic for the Operator Special Function Keyboard.

The main portion of the MCI is located in the CALMS system's extension mounting box. The logic is implemented in a BB11 system unit utilizing an M1710 Unibus Interface Foundation card and several special cards. The MCI interfaces between the PDP-11 Unibus, the Operator Stage Motor Control unit and the Stage Motor Drive and Limit and Position Switch Circuits; between the PDP-11 Unibus and the Spread Detection and Auto-Focus hardware; and between the PDP-11 Unibus and the Operator Special Function Keyboard circuit. There is also an interface to a decade stage position display.

The MCI is capable of driving each motor independently of the other two. The operator may move a motor either by single steps or by slewing. The operator may control the motors only when the MCI is in Operator Mode. The computer can command a motor to move in either direction from 1 to 2^{15} steps. A computer move may be either a number of steps relative to a motor's present position or to an absolute motor position. The MCI must be in computer mode for a computer commanded move.

1. Specifications

<u>Stage Motor Step Resolution</u>: 10 microns/step in the X and Y directions. 0.1 micron/step in the Focus direction.

<u>Stepping Rate</u>: 400 steps/second - all motors.

<u>Power</u>: +5VDC, Amps.

B. INTERFACING REQUIREMENTS

1. Hardware

The interface to the PDP-11 Unibus is implemented by a M1710 Unibus Interface Foundation card. The Device Addresses and Interrupt Vector Addresses are set by the proper jumpering on the card. The desired Bus Request level line must be wired from the M1710 card connector to the Unibus connectors on the BB11 and the matching Bus Grant line broken and run from the Unibus connectors through the M1710 connector.

The equipment physically located apart from the MCI are connected to it by cables. High speed signal lines are differentially driven twisted pairs. Slow speed signal lines are open collector driven single lines with resistor termination on the signal receiver ends.

2. Software

MCI Initialization: The MCI is initialized by the Unibus INIT signal. This signal causes the termination of any move in progress, cancels all interrupt requests and disables all interrupts. The cumulative position registers are not affected by INIT.

Motor Drive and Cumulative Position Register: Each of the three motors has two registers that share the same Device Address code. The MOTOR Drive is a write-only register that accepts the 2's complement of the number of steps the motor is to be moved. The Cumulative Position Register (CPR) is a read-only register that contains the step position of the motor.

Absolute Motor Move: This operation is performed by the computer instruction SUB S D, where

S = Location containing the true value of the motor position to be moved to.

D = The Motor Drive Device Address Register of the motor to be moved.

Relative Motor Move: This operation is performed by the computer instruction MOV S D, where

S = Location containing the 2's complement of the number of steps the motor is to be drive.

D = The Motor Drive Device Address Register of the motor to be driven

The driving direction is defined by the sign of the relative move word. For a positive motor drive S would contain the 2's complement of a positive number.

Computer Mode: The MCI must be in Computer Mode for a computer move command to be executed. There are several ways the MCI can be put into and/or maintained in Computer Mode.

A) The Operator Mode request signal from the Operator Stage Motor Control unit is not true. This condition always places the MCI in Computer Mode. This signal is not under computer control.

B) Computer setting bit 13 true in the MCI SMSC register will inhibit the Operator Mode Request signal true from switching the MCI to Operator Mode. This control bit is only effective if the MCI is in Computer Mode. Therefore, if the bit is set while the MCI is in Operator Mode, the inhibition will only become active when either the operator turns off the Operator Mode Request signal or the computer controlled Capture MCI bit is set (bit 14 in the SMSC register).

C) Computer setting bit 14 true in the MCI SMSC register will immediately switch the MCI to Computer Mode if it is in Operator Mode and will inhibit the Operator Mode Request signal.

Motor Busy: A computer move command to a motor should not be made while that motor is busy from a previous command. The motor busy status bit on the SMSC register (bit 11, 7 or 3) should therefore be checked prior to a computer move command.

Stage Limits: The microscope stage has an upper and a lower limit of travel in each of its 3 degrees of movement (X, Y and Focus). These limits are defined by switches on the stage. Whenever a limit switch is encountered during a motor move while the stage is between that motor's associated limit switches, the move is terminated, the motor's Operation Complete Interrupt Request is generated and the motor busy status bit is set to not busy. As long as the stage is in contact with the limit switch, any further commands to move in the direction of the switch will result in a move of zero steps with the above termination. The stage motor will still respond normally to move commands in the opposite direction.

The stage limit switch conditions are available on the SMSC register. They should be examined at the completion of each computer commanded stage move.

Cumulative Position Register Initialization: Each motor CPR may be initialized to its maximum negative value (-2^{+15}) by setting its corresponding bit in the SMSC register. The bits are write-only, and need not be reset subsequent to an initialized CPR operation. The same operation initializes the respective Decimal Cumulative Position Register to zero.

Filter Position and Objective Turret Position: Two 3-bit read-only words on the IEAPD register.

Enable Interrupt: Several circuits in the system generate interrupt requests. They are the Operator Special Functions keys, Spread and Focus Data Ready, Motor Operation Complete and Operator to Computer Mode transition. In order for a request to cause an interrupt to the computer, its interrupt circuit must be enabled by setting the proper bit in the IEAPD register. A request generated prior to enabling will be lost.

Interrupt Vector Address: Each interrupt request generated in the MCI in turn generates a unique interrupt vector address. There is a priority scheme to handle coincident requests. The request with the highest vector address will take precedence and the other(s) will be held in abeyance until the highest request has been honored. The highest remaining request will then generate an interrupt. The sequence continues until all requests have generated an interrupt. Figure 4-2 lists the interrupt requests and their associated vector addresses and enabling bits.

Spread Data Word and Focus Data Word: These are two read-only registers. Their contents are summarized in the DAR attachments. Further detail is available in the Spread and Auto Focus Hardware documentation.

C. THEORY OF OPERATION

Figure 4-1 represents an overall block diagram of the stage Motor Control Interface (MCI). A synopsis of the role of each block is as follows:

MCI/Unibus Handshaking, Device Address Decoding and Interrup Multiplexing: These functions are implemented on a single DEC M1710 Unibus Interface Foundation card. They provide the necessary signals and timing for Unibus utilization, decoding to read and write the MCI and the Spread and Focus parameter Device Address Registers (DAR) and a multiplexing circuit for the MCI and Spread and Focus systems interrupts.

X, Y and Focus Motor Drive Stimulus and Position Circuits (3): Each circuit provides the stimulus to position its stepping motor in response to inputs from either the computer or the operator stage motor control unit, maintains a binary cumulative value of the motor position and provides the drive to the Decimal Cumulative Position Display Circuit.

MCI Control Circuits: Contains the buffer register for the signals from the stage limit switches, a circuit to control the MCI's source of input (operator or computer) and a circuit for the initialization of the various cumulative motor position registers.

MCI Unibus Data Line Receivers and Drivers: These are required buffers between the Unibus data lines and the MCI DAR's.

Spread and Focus Parameter Data Multiplexing Circuit: Provides the computer interface for the two Spread and Focus DAR's.

X, Y and Focus Motors Drive Circuits: These circuits receive the motor drive stimuli and amplify them to provide the drive for the stepping motors.

Stage Limit Switches: The switches that are activated whenever the stage is being driven past any of its X, Y, or Z limits.

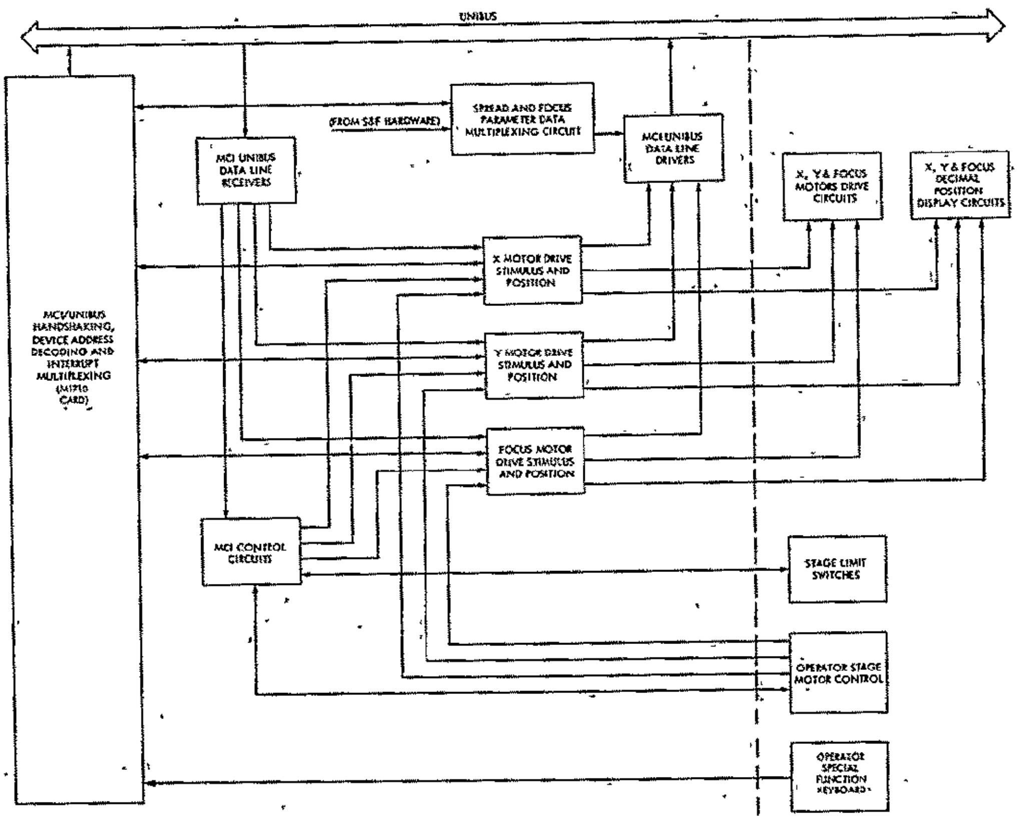


Figure 4-1 MCI System Block Diagram

<u>Operator Stage Motor Control</u>: A unit with which the operator, through the use of its two joysticks and its pushbuttons, may remotely control the microscope's stage positions.

<u>X, Y and Focus Decimal Display Circuits</u>: These circuits drive front panel displays of the stage position in microns.

<u>Operator Special Function Keyboard</u>: This is a keyboard mounted on a CALMS system front panel consisting of 12 keys, 11 of which are active. Each active key generates a unique interrupt request that causes the computer to perform a specific processing related function.

<u>Elementary Theory of Operation</u>: For all computer-MCI operations, except the interrupt, the MCI is the bus slave. The M1710 card provides all the necessary Unibus handshaking signals and buffering

Data Transfer, Computer to Device Address Register (DAR): The M1710 card decodes the Unibus address lines and control lines. If the address code is one of the MCI DAR's the M1710 generates a strobe to it, causing the data to be transferred. (All write DAR inputs are daisy-chain connected to the Unibus data lines via the receiver-buffers on the M1710.)

Data Transfer, DAR to Computer: The M1710 card decodes the Unibus address lines and control lines. If the address code is one of the MCI DAR's the M1710 generates a strobe that places the DAR's contents onto the Unibus Data lines. (All read DAR outputs are bussed together through tristate gates and, in turn, to the Unibus Data lines via the data line drivers on the M1710.)

Computer Commanded Motor Move: The Motor Drive Register (MDR) is loaded by the computer. The Motor Drive Stimulus and Position circuit sets Motor Enable (MENABLE) and Motor Busy (BUSY). With each motor clock pulse the MDR, CPR and Decade Cumulative Position Register are counted and a motor drive stimulus pulse is sent to the Motor Drive circuit, up if the MDR most significant bit is true, down if the MDR most significant bit is false. The operation continues until the MDR is all zeros. MENABLE and BUSY are then reset, causing an Operation Complete Interrupt request.

Operator Commanded Motor Move: Pulses are received from the Operator Stage Motor Control unit for either a motor "up" or "down" move. Each pulse is used to count the CPR and the Decade Cumulative Position Register in the associated direction and to send a drive stimulus pulse to the Motor Drive circuit. The MDR and other circuitry is unaffected.

Interrupts: The MCI is capable of accepting 16 interrupt request signals and, through priority logic, generating 16 unique Interrupt Vector Addresses and performing the necessary operations required to interrupt the PDP-11 (see Fig. 4-2). The interrupt requests, their Interrupt Vector Addresses and their associated Interrupt Enable bits on the IEAPD register are listed in Figure 4-2.

Each interrupt request signal is used to load a 1 in its assigned bit position in the 16-bit Interrupt Request Register (IRR), given that that interrupt request has been enabled by the computer. If not enabled, the request is lost. Whenever the IRR is non-zero, the priority logic circuit generates bits 2 - 5 of the Interrupt Vector Address for the highest priority request active in the IRR and generates a strobe to the M1710 card's interrupt circuit. (The remaining Interrupt Vector Address bits are generated by fixed wiring on the M1710 card.) The strobe causes the interrupt circuit to perform the required handshaking with the computer for an interrupt operation. At the completion of the interrupt operation, the requesting bit in the IRR is reset.

REQ. NUM.	INTERRUPT REQUEST NAME	INTERRUPT VECTOR ADDRESS (OCTAL)	IEAPO ENABLE BIT
*00	SPECIAL FUNCTION KEY 1	*000300	03
01	" " " 2	" 304	04
02	" " " 3	" 310	04
03	" " " 4	" 314	05
04	" " " 5	" 320	06
05	" " " 6	" 324	06
06	" " " 7	" 330	06
07	" " " 8	" 334	06
08	" " " 9	" 340	07
09	" " " 10	" 344	08
10	" " " 11	" 350	09
11	FOCUS MOTOR OPERATION COMPLETE	" 354	01
12	Y " " "	" 360	01
13	X " " "	" 364	01
14	MCI OPERATOR-TO-COMPUTER MODE	" 370	00
**15	SPREAD AND FOCUS DATA READY	**000374	02

*LOWEST PRIORITY
**HIGHEST PRIORITY

Figure 4-2 MCI Interrupt Requests

Detail Theory of Operation

Figure 4-3 lists the cards that comprise the main portion of the MCI and depicts their layout within the BB11 system unit. The following is a detailed description of the operation of each card type and any special requirements or procedures:

<u>M1710 Unibus Interface Foundation Card</u>: The computer handshaking operations of the M1710 card are explained in detail in the various DEC M1710 manuals. There is, however, some special wiring that is done on an M1710 card to configure it as a unique device on the Unibus. One such operation is to define the base device address:

The M1710 is capable of decoding 16 DAR codes. The address codes are consecutive Unibus word addresses, the lowest being the base address. To define this address, the buffered Unibus Address bits 5 - 12 must be appropriately wired (true or complement) to the decoding logic gate E38 of DEC deawing M1710-0-1, Sheet 2. The base address wiring for the MCI is shown on JPL drawing MCI Interrupt Request Logic - M1710.

When the M1710 decodes a Unibus address assigned to it, it enables a select line SEL N, where N is the Octal device address relative to the M1710's base device address. The select signal is combined with the decoded output of the two Unibus control lines, C0 and C1, to generate a strobe signal to the associated DAR. The strobes generated are SEL N IN H for data transfers from the MCI to the computer and SEL N OUTLO H for data transfers from the computer to the MCI. The strobe circuits are implemented on the OEM portion of the M1710 card (JPL drawing MCI Interrupt Request Logic - M1710).

The M1710 generates the required handshaking signals for computer interrupt operation. The special wiring required is listed on JPL drawing MCI Interrupt Request Logic - M1710. Part of this special wiring is the defining of the Interrupt Vector Address.

The Interrupt Vector Address is defined on bits 2 - 8, all other bits being zero (i.e., false). As the MCI has ly possible interrupt requests, bits 2 - 5 are defined by the priority circuit for the specific interrupt requests, and bits

	A	B	C	D	E	F	
4	UNIBUS CONNECTOR (OUT)		M1710 INTERFACE FOUNDATION CARD				4
3	POWER		MCI CONTROL CARD				3
2	(RESERVED)		FOCUS MOTOR DRIVE STIMULUS AND POSITION CARD (FMDSP)		Y MOTOR DRIVE STIMULUS AND POSITION CARD (YMDSP)		2
1	UNIBUS CONNECTOR (IN)		SPREAD AND FOCUS RECEIVER/MUX AND MOTOR CLOCK CARD		X MOTOR DRIVE STIMULUS AND POSITION CARD (XMDSP)		1

PIN SIDE

Figure 4-3 CALMS MCI Card Layout (DEC BB11 Systems Unit)

6 - 8 are defined by hard writing. Figure 4-2 lists the interrupt requests, their associated vector addressed and their associated interrupt enable bits on the IEAPD register.

The MCI portion of an interrupt operation is performed by the following steps (referring to JPL drawing MCI Interrupt Request Logic - M1710 and Fig. 4-4.)

1. An interrupt request signal gates its bit in the Interrupt Request Register (IRR). If that request is enabled its bit will be set true.

2. When the IRR is non-zero the priority circuit will create the vector address bits 2 - 5 for the true request with the highest priority and initiate the Interrupt Request Strobe.

3. The INT REQ STROBE gates the vector bits 2 - 5 into the vector bit register and initiates action in the M1710 interrupt circuit, which performs the required handshaking with the computer.

4. At the end of the interrupt cycle (INTR DONE) the vector bits 2-5 are decoded to reset the requesting bit in the IRR.

5. If at the fall of INTR DONE another bit is true in the IRR the operation will repeat, starting at step 2.

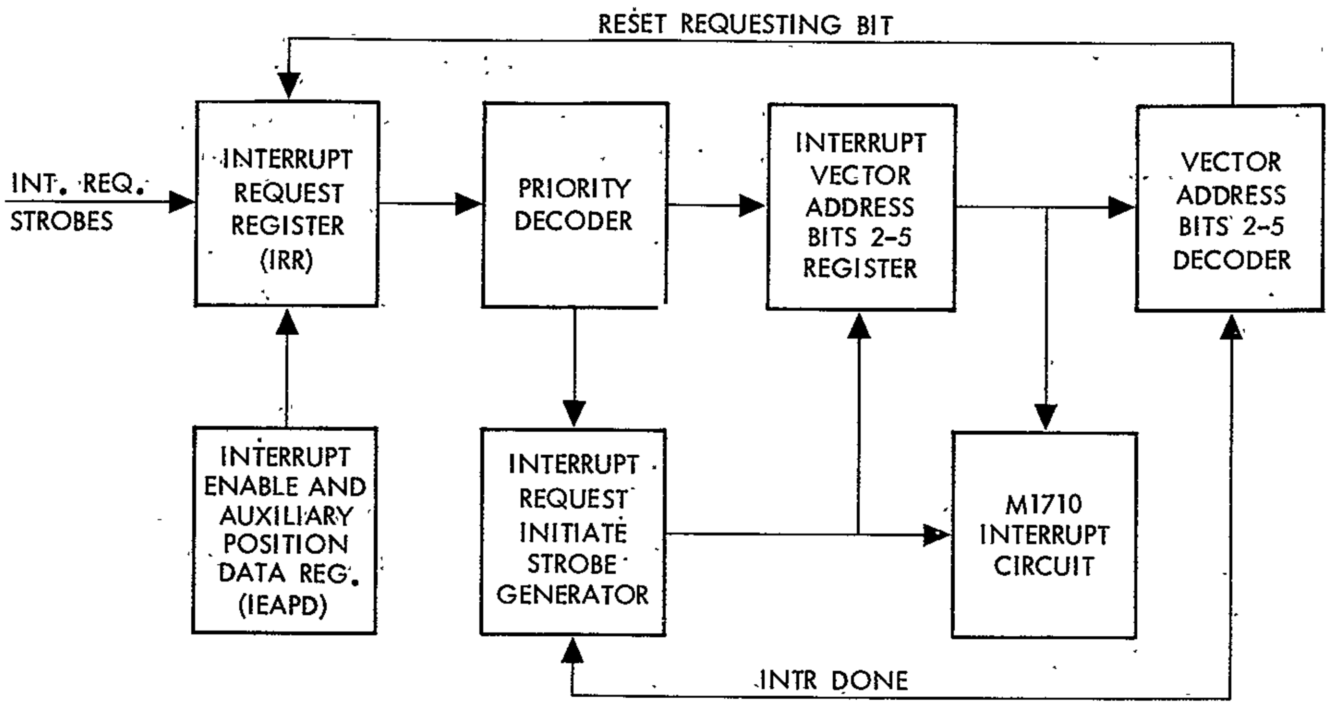


Figure 4-4 CALMS MCI Interrupt Request Circuit Block Diagram

The interrupt request bit for the Spread and Focus Data Ready Interrupt Request (SFDRI) is enabled by both the IEAPD register and a delay circuit that prohibits this request until the stage motors have been still for 150 milliseconds. This is done to allow for stage mechanical setting.

MCI Control Card: This card (as well as all of the remaining to be discussed) is a DEC OEM card containing JPL designed circuitry. A portion of the card (drawing sheet 1) contains the remainder of the interrupt request circuits that could not be put on the M1710 card. The card also contains the IEAPD register and the SMSC register.

The Operator/Computer Mode control circuit is implemented on the MCI Control Card. It is basically an RS latch with the following SET and Reset equations:

$$\text{SET} = \text{Computer Mode} = \overline{\text{OMODE REQ}} + \text{CAPTURE M(}$$

$$\text{RESET} = \text{Operator Mode} = \text{OMODE REQ} \cdot \overline{\text{CAPTURE MCI}} \cdot \overline{\text{INHIBIT OMODE}} \\ (\overline{\text{XBUSY}} \cdot \overline{\text{YBUSY}} \cdot \overline{\text{FBUSY}})$$

MCI Control, Sheet 2 shows the differential drivers for the motor stimulus and Initiate CPR pulses, and the differential receivers for the limit switches, the filter position and the turret position bits.

X, Y and Focus Motor Drive Stimulus and Position Cards: These cards control the drive stimulus to the stage motor drive circuits and maintain a binary record of the motors' positions relative to the initialized positions (see Fig. 4-5).

The Motor Drive Register (MDR) is 4 4-bit up/down binary counters connected in cascade. The register is preset by the computer with a non-zero value to initiate a computer motor move. The register outputs are connected to a Nor-Nand circuit to check for the register non-zero state. When in that state (non-zero) the BUSY and MENABLE circuits are true, allowing the directional motor stimulus pulses through to the motor drive circuit and allowing the MDR, CPR and Decade Cumulative Position Register (DCPR) to be counted. Counting direction depends upon the MSB of the MDR, the MSB true being the forward/up direction. These circuits are active only when the MCI is in Computer Mode.

The Cumulative Position Register (CPR) is also 4 4-bit up/down binary counters connected in cascade. The CPR is counted up or down once for each motor drive stimulus up or down pulse, respectively. The outputs of the CPR

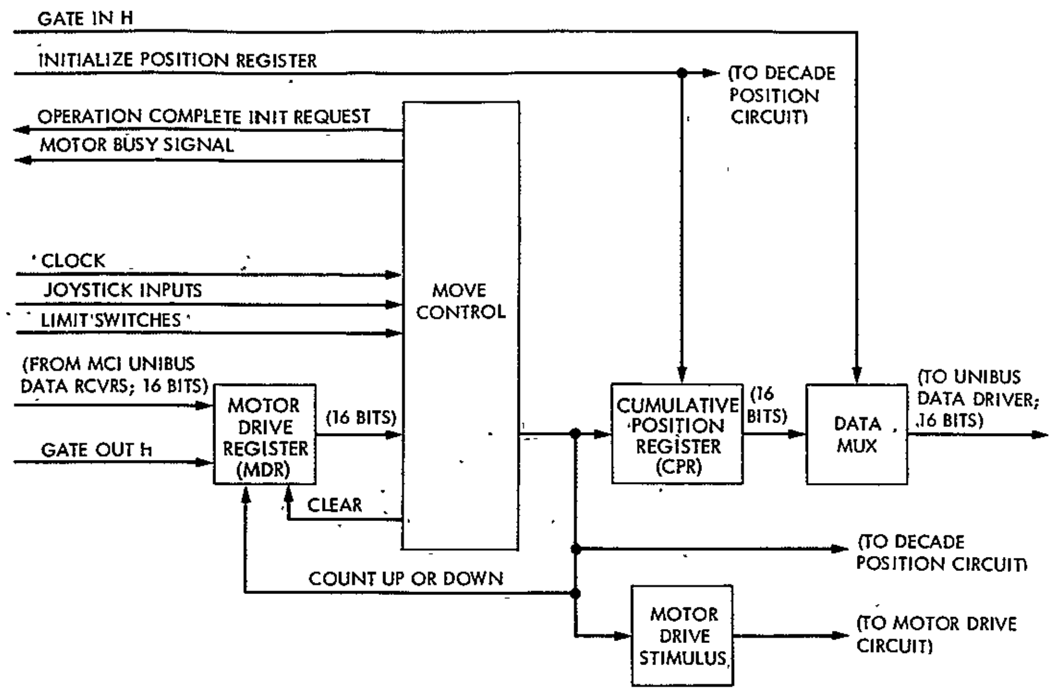


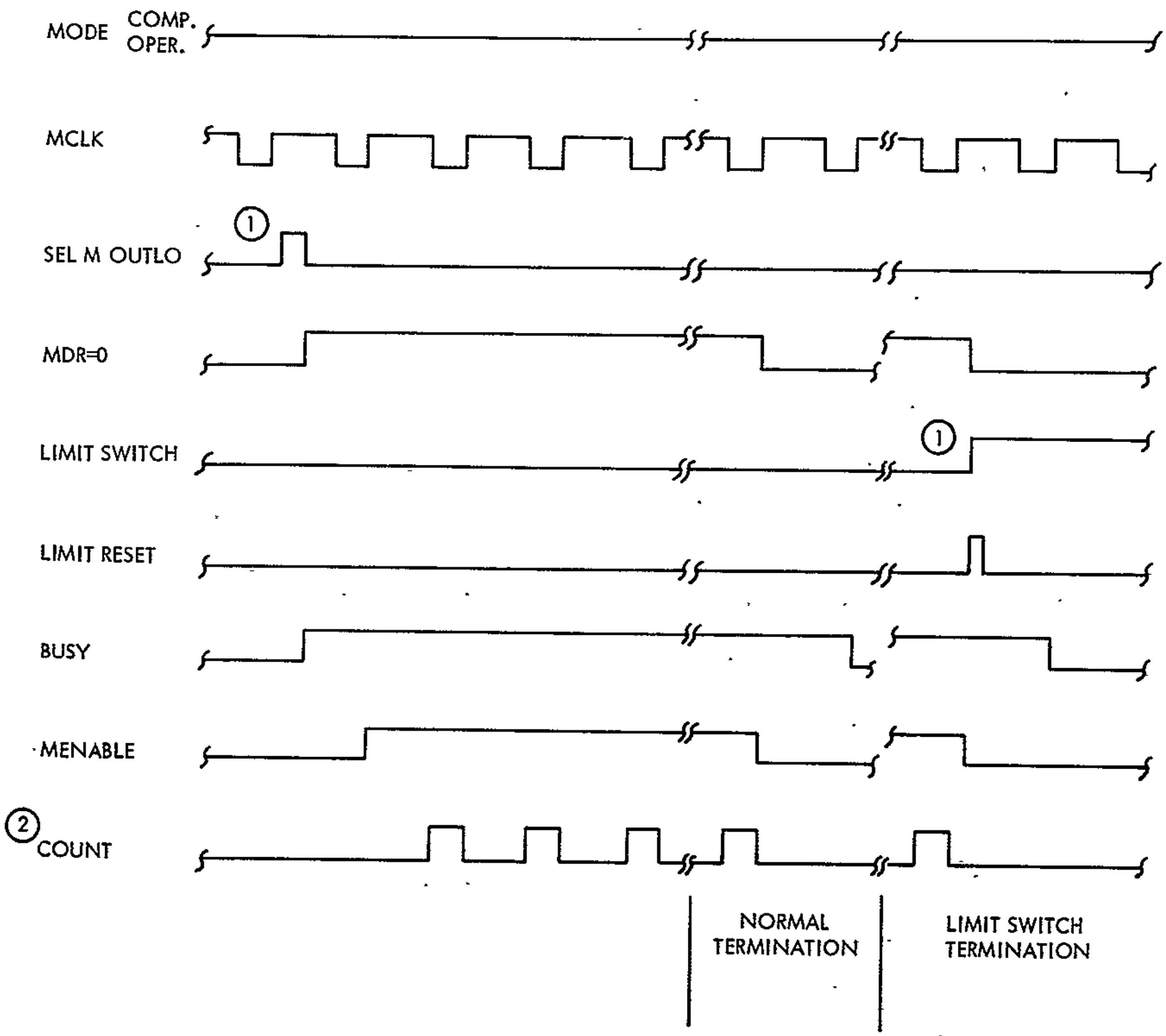
Figure 4-5 X, Y or Focus Motor Drive and Stimulus

are connected to the MCI data bus through tristate devices. The CPR may be preset to the maximum 2's complement negative value by setting a 1 in the respective motor's Initiate CPR bit in the SMSC device address register.

The Motor Drive Stimulus and Position card has inputs for up and down pulses from the Operator Stage Motor Control Unit (JSCUP and JSCDN). These pulses are fed through as motor drive stimulus and CPR and DCPR count pulses. The JSCUP and JSCDN pulses are enabled only when the MCI is in Operator Mode.

Figure 4-6 is a timing diagram of a motor move for a computer initiated move. Figure 4-7 is an operator controlled move timing diagram.

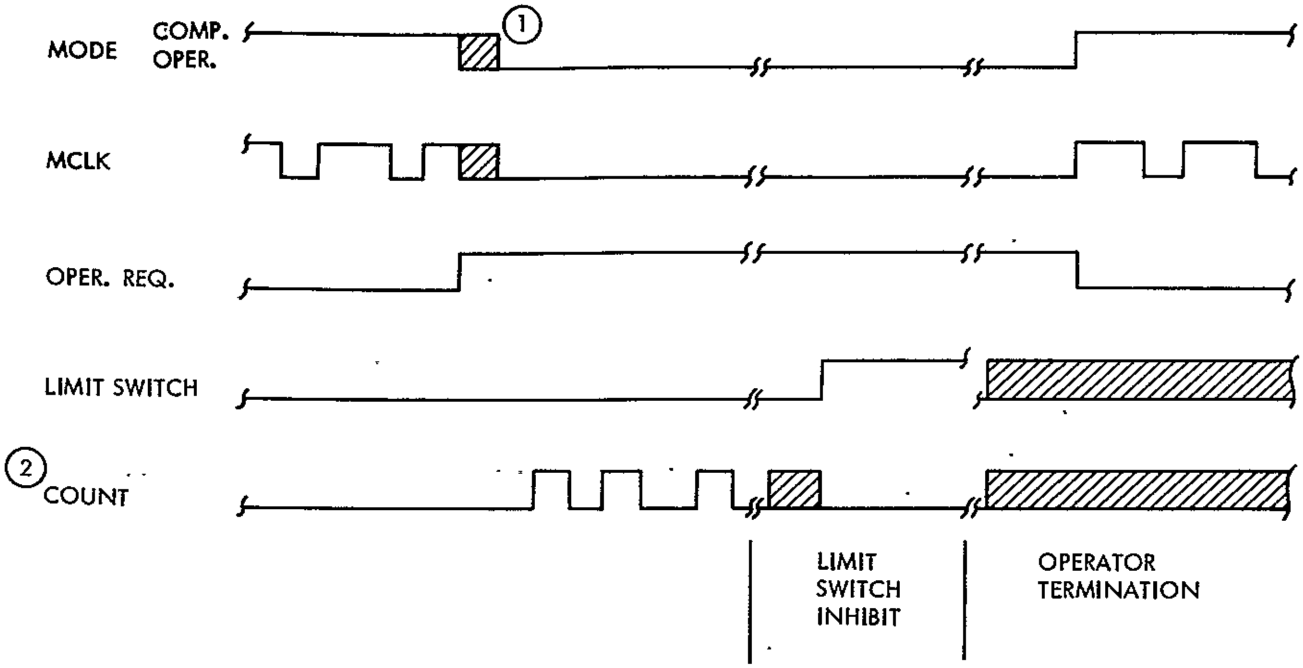
<u>SP/F Receiver - MUX and Motor Clocks</u>: This card contains the receiver network and the tristate MCI data line buffers for the Spread Data word and the Focus Data word, along with the differential receiver for the Spread and Focus Data Ready Interrupt Request signal (SFDRI).



NOTES:

1. THESE SIGNALS OCCUR INDEPENDENT TO MCLK
2. COUNT = UP & CUP, WHEN MDRMSB = 1
   = DN & CDN, WHEN MDRMSB = 0
3. THE DIAGRAM SHOWS THE TRUE (HIGH) AND THE FALSE (LOW) STATES OF THE SIGNALS, NOT THEIR VOLTAGE LEVELS. REFER TO THE LOGIC DIAGRAMS FOR THE CORRESPONDING VOLTAGE LEVELS.

Figure 4-6 Computer Initiated Motor Move Timing Diagram



NOTES:

① OCCURS WHENEVER MOTORS NOT BUSY AND CAPTURE AND INHIBIT CONTROL BITS ARE FALSE

② JSCUP AND CUP OR JSCDN AND CDN

③ THE DIAGRAM SHOWS THE TRUE (HIGH) AND THE FALSE (LOW) STATES OF THE SIGNALS, NOT THEIR VOLTAGE LEVELS. REFER TO THE LOGIC DIAGRAMS FOR THE CORRESPONDING VOLTAGE LEVELS.

Figure 4-7 Operator Initiated Motor Move Timing Diagram

The X-Y motor clock (XYMCLK) and the Focus motor clock (FMCLK) are implemented on this card. These clocks are enabled when the MCI is in Computer mode. (It is the disabling of the clocks when the MCI is in Operator Mode that disables the computer portion of the Motor Drive Stimulus and Position cards.)

Operator Stage Motor Control Unit: This unit (also referred to as the MCI Joystick Box) is a stand-alone tabletop device for the operator's control of the microscope's stage. The unit is connected to the MCI BB11 system unit via a cable. The unit's electronics is defined in the JPL Drawing "NICHD Joystick Box and Logic."

The Unit has 6 outputs that supply pulses to move the 3 motors forward (up) and reverse (down). The outputs are inhibited whenever the MCI is in Computer Mode. To put the MCI into Operator Mode the operator pushes the OPER mode control button, setting the Control Mode flipflop. A light is lit to indicate that the Operator Mode Request is true. When the MCI goes into Operator Mode the OPER indicator is lit. The unit is now enabled for operator use.

The slew pulses are generated by a Measurement Systems Model 522 digital joy stick for the X and Y motors and a Model 571 joystick switch for the Focus motor. Each slew pulse line is ORed with a pushbutton, schmitt trigger generated single step pulse. This signal line is connected to the 3-input Nand output gate. The other two inputs of the gate are used as enables. One input is enabled by MCI Operator Mode true. The other input is disabled by the switch encountered when that move pulse attempts to drive the stage beyond its operational limit. This enabling allows the operator to move the stage from outside the limits into the operational volume, but prevents him from doing the opposite.

The operator may return the MCI to Operator Mode by pushing the COMP mode control button. This immediately returns the MCI to Computer Mode and generates an interrupt request strobe.

Motor Drive Circuits: The Motor Drive dircuits are located in the microscope assembly. The 6 motor drive stimulus pulses are received from the MCI differentially and the up-down buffered pair for each motor is connected to the forward and reverse inputs, respectively, of a Computer Devices Model M43020 Motor Driver unit. Each motor driver provides the required phase sequencing to drive its Astrosyn stepping motor on the stage.

Limit Switch, Filter Position and Turret Position Circuits: The micro-switches defining the 6 stage limits, the filter position, and the magnification turret position are "de-bounced" by RS latches and differentially driven to the MCI.

Operator Special Function Keyboard: The keyboard is the means by which the operator may request the execution of a specific computer operation. The keyboard circuit consists of a Cherry Model B65-1712 keyboard, key de-bouncing circuitry, and open collector buffers to the MCI. Each time one of the 11 active keys is pushed and released, a unique interrupt request strobe is sent to the MCI. If that request is enabled, a unique interrupt is generated to the computer which is interpreted as a request for a specific operation.

Device Address Registers: The following pages list the bit assignments of the device address registers.

BIT #	I/O (R/W)	BIT DESCRIPTION	
		CPR (READ)	DRIVE STIMULUS (WRITE)
15	R/W		
14	"		
13	"		
12	"		
11	"		
10	"	CUMULATIVE	2'S COMPLEMENT
9	"	STEP	OF DESIRED
8	"	POSITION	CHANGE OF THE
7	"	OF	CUMULATIVE
6	"	MOTOR	POSITION
5	"		
4	"		
3	"		
2	"		
1	"		
0	"		

* REGISTER	BUS ADDR
XMDSP	764040
YMDSP	764042
FMDSP	764044

BIT #	I/O (R/W)	BIT DESCRIPTION
15	R	MCI MODE CONDITION (COMPUTER/OPERATOR = 0/1)
14	R/W	CAPTURE MCI
13	R/W	INHIBIT OPERATOR MODE
12		
11	R	X MOTOR BUSY
10	R	X UPPER LIMIT SWITCH
9	R	X LOWER LIMIT SWITCH
8	W	INITIALIZE X CUMULATIVE POSITION REGISTER (CPR)
7	R	Y MOTOR BUSY
6	R	Y UPPER LIMIT SWITCH
5	R	Y LOWER LIMIT SWITCH
4	W	INITIALIZE Y CPR
3	R	FOCUS MOTOR BUSY
2	R	FOCUS UPPER LIMIT SWITCH.
1	R	FOCUS LOWER LIMIT SWITCH
0	W	INITIALIZE FOCUS CPR

BIT #	I/O (R/W)	BIT DESCRIPTION
15	R	FILTER POSITION (MSB)
14	R	" "
13	R	" "
12	R	OBJECTIVE TURRET POSITION (MSB)
11	R	" " "
10	R	" " "
9	R/W	ENABLE INTERRUPT, SPECIAL FUNCTION KEY 11
8	R/W	" " " " " 10
7	R/W	" " " " " 9
6	R/W	" " " " " 5, 6, 7&8
5	R/W	" " " " " 4
4	R/W	" " " " " 2&3
3	R/W	" " " " " 1
2	R/W	" " , SPREAD & FOCUS DATA READY
1	R/W	" " , MOTOR OPERATION COMPLETE
0	R/W	" " , OPERATOR TO COMPUTER MODE

BIT #	I/O (R/W)	BIT DESCRIPTION
15	R	SPREAD PRESENCE (SP) 1 = SPREAD PRESENT 0 = NO SPREAD PRESENT
14	"	THRESHOLD CROSSING COUNT WITHIN LIMITS (COUNT V)
13	"	AREA WITHIN LIMITS (AREA V)
12	"	TV FIELD A (AFLD)
11	"	TV FIELD B (BFLD)
10	"	UNUSED
9	"	"
8	"	"
7	"	THRESHOLD CROSSING COUNT (MSB)
6	"	" " " "
5	"	" " " "
4	"	" " " "
3	"	" " " "
2	"	" " " "
1	"	" " " "
0	"	" " " (LSB)

BIT #	I/O (R/W)	BIT DESCRIPTION					
15	R	HIGH FREQUENCY CONTENT PARAMETER (MSB)					
14	"	"	"	"	"	"	
13	"	"	"	"	"	"	
12	"	"	"	"	"	"	
11	"	"	"	"	"	"	
10	"	"	"	"	"	"	
9	"	"	"	"	"	"	
8	"	"	"	"	"	(LSB)	
7	"	INTEGRATED OPTICAL DENSITY (IOD) PARAMETER (MSB)					
6	"	"	"	"	"	"	"
5	"	"	"	"	"	"	"
4	"	"	"	"	"	"	"
3	"	"	"	"	"	"	"
2	"	"	"	"	"	"	"
1	"	"	"	"	"	"	"
0	"	"	"	"	"	"	(LSB)

SECTION V

AUTOFOCUS/SPREAD DETECTION/UNIT

A. SYSTEM DESCRIPTION

1. Purpose and Function

The automatic focus and spread detector unit processes the video from the closed circuit TV (CCTV) camera in the image digitizing system and supplies the computer program with data regarding the focal sharpness of the optical image and the presence or absence of a metaphase spread in the field of view. The hardware receives video at the standard commercial rate (525-lines/30 frames, 60 fields per second with 2:1 interlace) from the Image Quantizing System. Parameters generated are input to the computer via the Motor Control Interface (MCI).

2. General Performance Specifications

There are four key measures of operational performance; search speed, garbage rate, miss rate, and focus time. These determine how well the system functions in routine use. Search speed is the average area on the microscope slide which may be covered per unit time. The search speed with the present system is 0.08 mm^2/sec using a 63X objective. Garbage rate is the ratio of false positives to total spread presence indications, expressed as a percentage. Here, performance is highly dependent on slide quality. Garbage rate has been as low as 10% on well prepared slides with clean background and as high as 80% on slides of poor quality. Typically, however, a 15-20% garbage rate has been experienced.

Another spread detection quality measure is miss rate, or percentage of metaphase spreads not detected throughout a searched region. In the absence of sufficient data, the miss rate is estimated to be about 5%. Focus time depends primarily on the initial focus condition and is typically 1 to 2 seconds. The effective focus capture range is approximately 25 times the objective depth of field centered about the position of maximum image contrast.

Spread detector and auto-focus unit performance can be summarized as follows:

Search speed	0.08 mm^2/second
Garbage rate	15-20%
Miss Rate	5% estimated
Focus time	1-2 seconds
Power required is:	+5VDC 2.0 Amps, +15VDC 0.25 Amps and -15VDC 0.25 Amps

3. Reference Article

"Metaphase Spread Detection and Focus Using Closed-Circuit Television," Johnson, E. T., and Goforth, L. J. Journal of Histochemistry and Cytochemistry Vol. 22, No. 7, July 1974, pp. 536-545.

B. INTERFACING REQUIREMENTS

1. Hardware

The unit receives separate video and sync inputs from the image quantizing system and outputs the focus and apread presence parameters to the MCI along with a "DATA READY" strobe. An additional video output is used for display of the threshold video and/or count on a standard TV monitor.

Electrical characteristics of the inputs and outputs are given below:

a) Video Input - 75 ohm impedance, 1.0Vrms nominal, white level positive.

b) Sync Input - 75 ohm impedance, TTL nominal levels, high during horizontal sync pulse. [Note: can easily be convered to EIA (0V to - 4V) sync levels or composite video]

c) Display Video Output - same as a) above. Will drive a 75 ohm line, but requires external sync.

d) Parameter Outputs - open collector TTL drivers.

e) DATA READY Output - Differential twisted pair driver (DM 8830 type).

The unit is configured in a 3-1/2 inch rack mount. Video lines and sync lines employ BNC connectors. The Parameter and DATA READY outputs utilize multiple twisted pair cables for connection to the MCI.

The two 16-bit words corresponding to the spread presence and focus quality parameters are input to the MCI, along with a "Data Ready" signal. The MCI provides the interface to transfer the parameters to the PDP-11, provided the stage stepping motors have not been pulsed for at least 150 milliseconds.

2. Software

The spread presence data word and the focus quality data word are two read-only registers. Their contents are summarized in Figs. 5-1 and 5-2.

BIT #	I/O (R/W)	BIT DESCRIPTION
15	R	Spread presence (SP) 1 = spread present 0 = no spread present
14		Threshold crossing count within limits (count 1/)
13		Area within limits (AREA V)
12		TV field A (AFLD)
11		TV field B (BFLD)
10		Unused
9		
8		
7		Threshold crossing count (MSB)
6		
5		
4		
3		
2		
1		
0		(LSB)

Figure 5-1 Spread Data Word Register

BIT #	I/O (R/W)	BIT DESCRIPTION
15	R	High frequency content parameter (MSB)
14		
13		
12		
11		
10		
9		
8		(LSB)
7		Integrated optical density (IOD) parameter (MSB)
6		
5		
4		
3		
2		
1		
0		(LSB)

Figure 5-2 Focus Data Word Register

Typical slide search and focus operations are described in the remainder of this section.

Slide Search Operation

The slide search operation is carried out with the computer moving the stage in a systematic pattern. Search patterns available for operator selection include horizontal or vertical boustrophedon and rectangular spiral. The stage is made to pause at regular intervals corresponding to continuous TV fields of view. This pause permits stage settling and fading of any residual image on the TV camera tube. The computer then accesses the spread presence data word and tests bit 15 (SP). If SP = 1, the stage X and Y coordinates are accessed and stored in an array in computer memory so that such stage positions may be revisited later. If SP = 0, the stage moves again without logging the stage position. In one optional mode of searching, the stage remains at each spread position for image evaluation until the operator pushes a button to resume. In another optional mode, the microscope undergoes an auto-focus sequence at equidistant points along the search path. The remaining bits of the spread presence data word are not normally used in operation, but are useful in obtaining performance data. Bits 11 and 12 show from which of the interlaced TV fields the parameters were derived. A logic one alternates between bits 11 and 12 to indicate TV field A or B.

Automatic Focusing

A flow diagram of the basic focus algorithm for optimizing the focus parameter(s) is shown in Fig. 5-3. Initially, the focus quality data word (F) is read by the computer. If F is sufficiently large, indicating image presence, the first move is commanded in an arbitrarily fixed direction along the Z or focus axis. The computer pauses for stage and CCTV settling and then reads the new F. This move-read sequence is repeated as long as F increases. When F decreases after a move, a reverse move is made toward the peak F position. An extra incremental move is commanded to compensate for the calibrated mechanical backlash in the Z axis gearing. If the stage is initially positioned on the other side of peak F, the first move will cause a decrease in F. In this case,

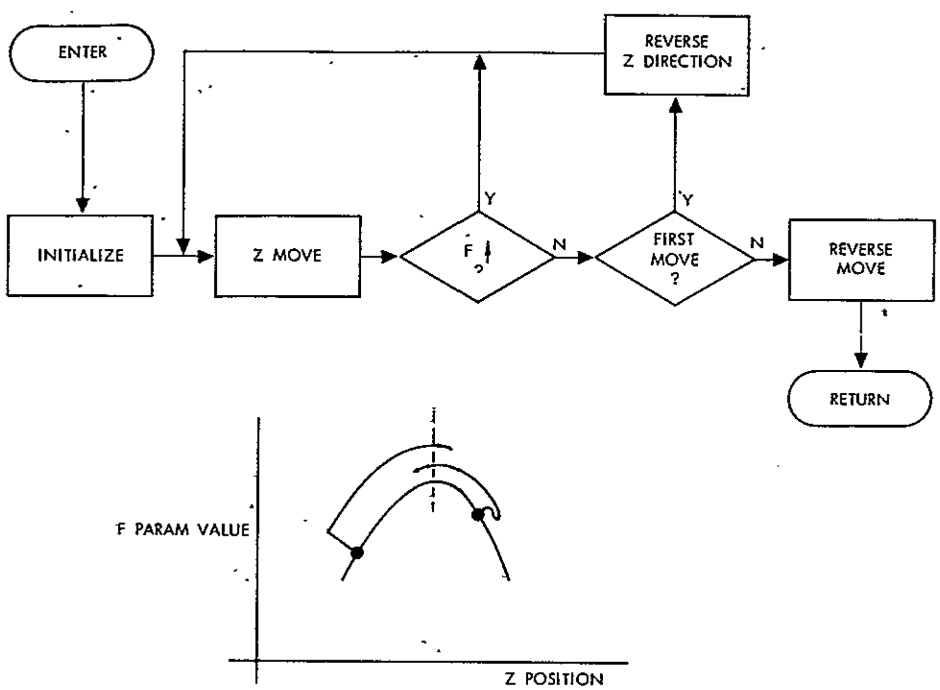


Figure 5-3   Basic Focus Algorithm

the direction will be reversed and then the move-read sequence is carried out as described. The uniform size of each Z move is determined chiefly by the depth of field of the objective lens. The move must also be large enough for the circuitry to provide statistically significant parameter value differences in the presence of video noise. The move size presently used is 0.8 microns with the 100X objectives. The Z axis stepping motor provides movement in steps of 0.1 micron at the rate of 250 steps per second.

C. THEORY OF OPERATION

1. Elementary Theory of Operation

The CCTV video is used to generate focus quality and spread presence parameters at the TV field rate of 60 per second. These parameters are passed to the computer which controls movement of the microscope stage through the operating software. Depending on the desired function, focusing or metaphase finding and the parameter values, a maximum of four words may be read by the computer at every TV field:

a) Spread presence parameter

b) Focus parameters (two)

c) X stage coordinate value

d) Y stage coordinate value

During slide search, the computer moves the stage, waits for a spread presence parameter, and then decides whether to log stage coordinates before moving the stage. The moves are controlled by the computer to search the slide in a systematic pattern selected by the operator. The size of each move is determined by the field of view of the particular microscope objective lens in use. For focusing, the microscope fine focus knob is driven by a digital stepping motor to maximize the two focus parameters, taking backlash into account. Again, the size of each move is determined by the microscope objective in use.

The spread presence parameter is based on the number of valid threshold crossings during a TV field. A valid threshold crossing is obtained whenever the video goes above a preset threshold density for a time period within prescribed limits. These limits correspond to the minimum and maximum chromosome dimensions as will be explained later. In addition to counting valid threshold crossings, the hardware checks the total area of objects within the field of view. Indication is provided when the area is sufficient to be a metaphase spread. The spread presence parameter occupies 11 bits of the 16-bit computer word. Three bits are used for indication of spread presence, count within limits and area within limits. The actual 8-bit count is also included.

Two focus parameters are generated. One is based on the high spatial frequency content of the video; the other uses the distribution of optical density.

Every TV field (one sixtieth of a second) a 16-bit word may be passed to the computer. The high-order 8-bits contain the high frequency content focus parameter; the low order 8-bits are the density derived focus parameter. The operating software uses a linear combination of both parameters determined by the specimen image content.

2. Detailed Theory of Operation

This section explains the theory of operation in detail. For clarity, the functions of spread detection and automatic focusing are described separately. An overall block diagram is included with the four schematics (analog circuits, sync circuits, counter and register circuits, and display, control, and meter circuits) to assist in correlating the detailed hardware block diagrams with the schematics.

Metaphase Spread Detection

The basic method of metaphase spread detection can be described with reference to Fig. 5-4. A TV scan line is shown to illustrate types of objects that may be encountered: an undivided nucleus, three chromosomes in "worst case" orientations, and a small dust particle. Below the scan line are shown the threshold output and the valid threshold crossings. A valid threshold crossing is obtained whenever the video falls below threshold density after being above threshold for a time period which is within prescribed limits. These limits (Tmin and Tmax) correspond to the minimum and maximum chromosome dimensions. The number of valid threshold crossings during a TV field must be within specified minimum and maximum limits for the "COUNT" criterion to be satisfied indicating a possible metaphase spread is in view. There is an additional "AREA" criterion which must be met before spread presence is indicated. The area above threshold is determined by integrating the threshold output for each entire TV field. If the integrator output is within specified limits, the AREA criterion is met.

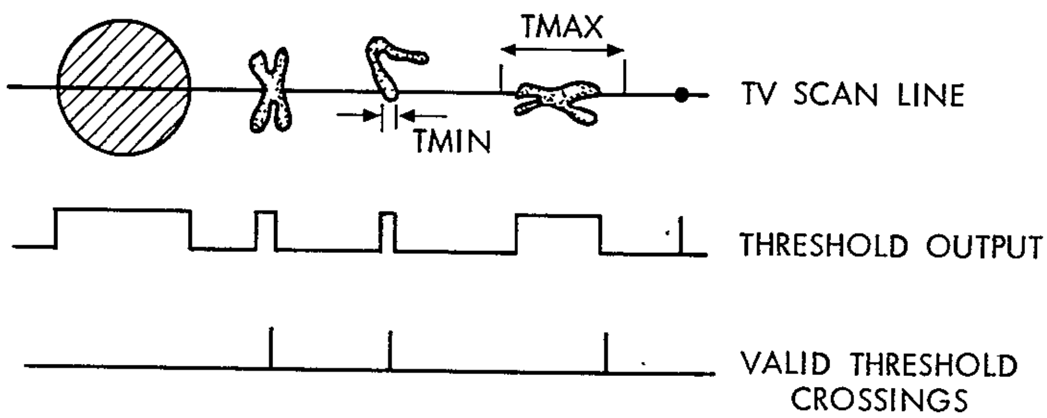
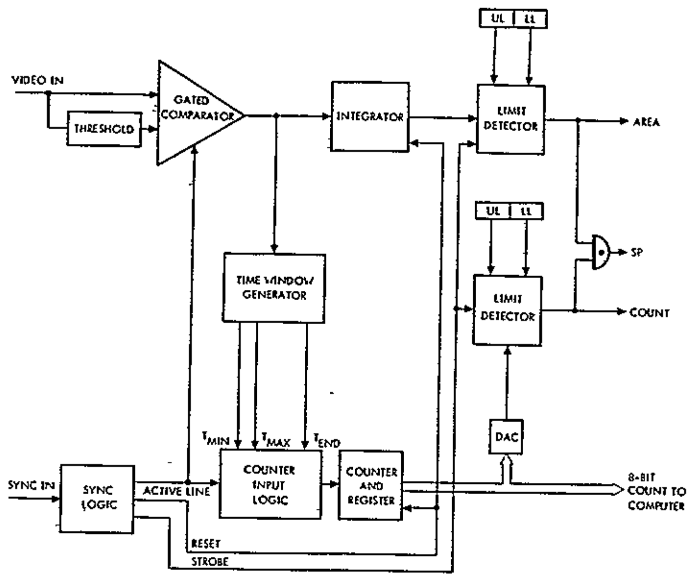


Figure 5-4 Spread Detection Waveforms

The hardware implementation for spread detection is shown in the block diagram, Fig. 5-5. The video input is from the CCTV camera operating at the standard commercial TV format (525 lines, 60 fields per second, interlaced 2:1.

The synchronization (sync) from the CCTV camera is used to generate an active line signal (AL) which gates a video comparator (NE529K) to produce a threshold output only during the central 80% of each TV scan line. This, along with the application of a small amount of low-pass filtered video to the comparator, in addition to the variable threshold voltage, helps compensate for TV camera shading. The threshold output is integrated during each TV field and the integrator output compared with preset upper and lower limits (UL and LL) in a double-ended limit detector at the end of each TV field (STROBE). The AREA limit detector output (ALIM) is held during the next TV field, but the integrator is reset to allow operation during the next TV field. The time window generator and counter input logic allow only valid threshold crossings to be counted during each TV field. The count at the end of each TV field is held



AREA - THE AREA DARKER THAN THRESHOLD IS WITHIN PRESET LIMITS.
COUNT - THE NUMBER OF VALID THRESHOLD CROSSINGS IS WITHIN PRESET LIMITS
SP - AREA AND COUNT BOTH TRUE INDICATE SPREAD PRESENCE.

Figure 5-5 Spread Presence Hardware Block Diagram

in a register which may also be read by the computer; the counter is reset during vertical retrace in preparation for the next TV field. The 8-bit COUNT held in the register is converted to an analog voltage (in the DAC) and compared with preset upper and lower limits in the same manner as the AREA limit detector (CLIM). Spread presence (SP) is indicated when AREA and COUNT are both within limits.

Automatic Focusing

Focusing is accomplished by maximizing either of the two focus parameters, or both. Integrated optical density (IOD) is one of the measures of focus quality which has been implemented. It assumes that the best focus is obtained when the integrated optical density of the specimen above a threshold is maximized. The other focus measure is high spatial frequency content. An image loses high spatial frequency energy as it goes out of focus. High spatial frequency energy content can be determined from the amount of video present at high temporal frequency. For either method (IOD or high frequency), the hardware generates the parameter relating to focus quality and the computer drives the microscope stage in the focus direction so as to maximize the parameter.

The focus parameter hardware is shown in Fig. 5-6 in block diagram form. To obtain the high frequency (HF) focus parameter, the input video is passed through a bandpass filter, rectifying gated amplifier (MC 1545), integrator and analog-to-digital converter (ADC). The sync logic controls the operation of the hardware. The bandpass filter is a simple R-C network having upper and lower cutoff frequency of 2.5 MHz and 150 kHz, respectively. These frequencies correspond roughly to the fundamental frequency range of the chromosomes and represent a compromise between high frequency signal and high frequency noise. The gated amplifier is turned off during blanking to prevent sync information from contributing to the high frequency content. The integrator is reset at the end of each TV field after analog-to-digital conversion.

The integrated optical density focus parameter is obtained by integrating the output of a high frequency operational amplifier, which functions as a blanking amplifier, and a precision half-wave rectifier and differential amplifier with variable offset (threshold) (an LH0032C operational amplifier with diode feedback). This is shown in Fig. 5-6.

The output of the half-wave rectifier and differential amplifier is an amplified positive replica of video which corresponds to an optical density above the IOD threshold during the active TV lines. As can be seen from the waveforms of Fig. 5-7, the blanking serves to force the video below threshold (in terms of optical density) during the line sync time intervals. Optical density is not directly proportional to the video signal, but is related to its logarithm. However, for fairly low density objects, such as chromosomes, this approximation does not introduce significant error. The output of the half-wave rectifier and differential amplifier is integrated and amplified before digitizing at the end of every TV field. After digitizing, the integrator is reset, but the digitized output is held in a register.

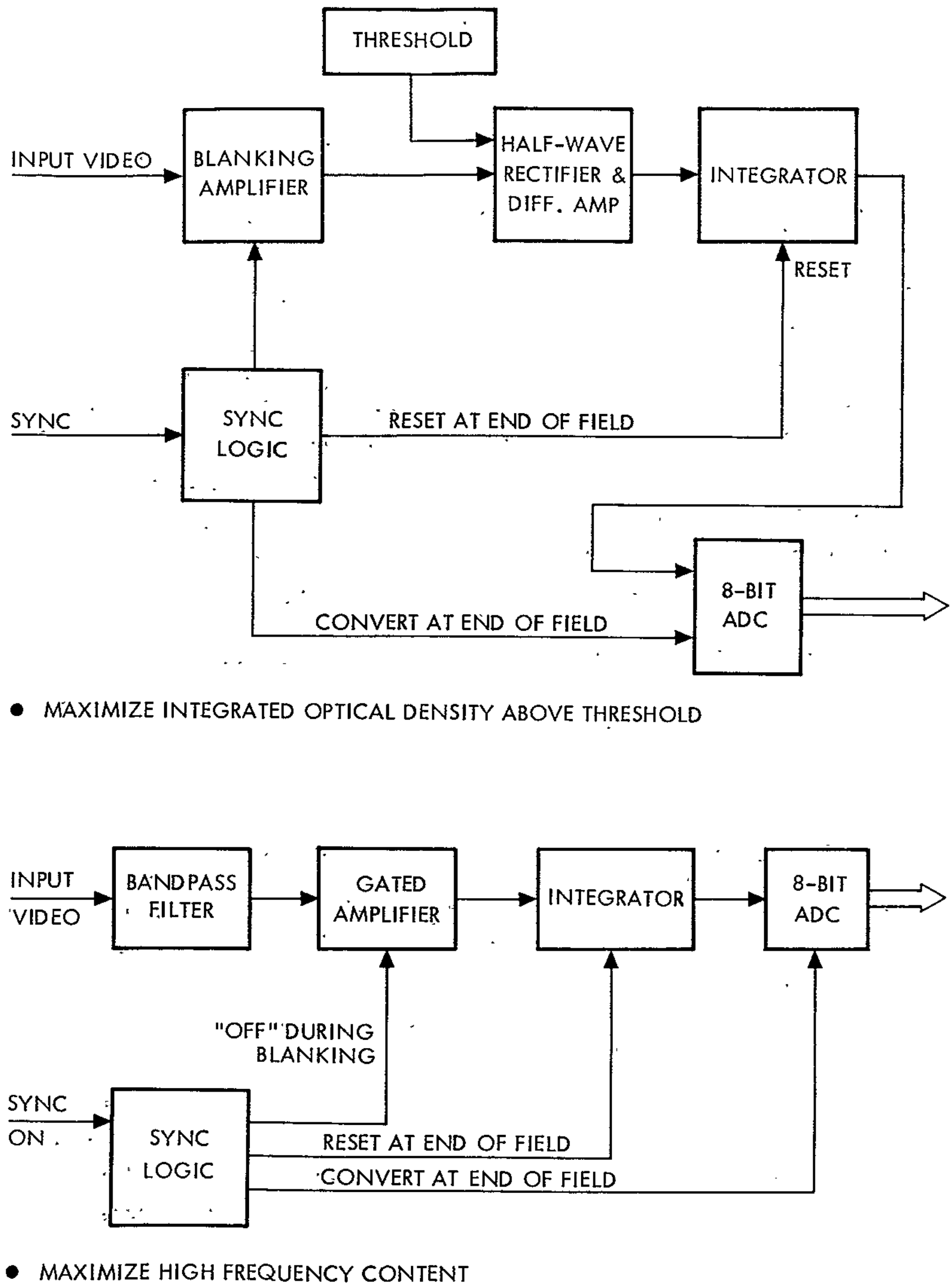


Figure 5-6   Focus Parameters Hardware Block Diagram

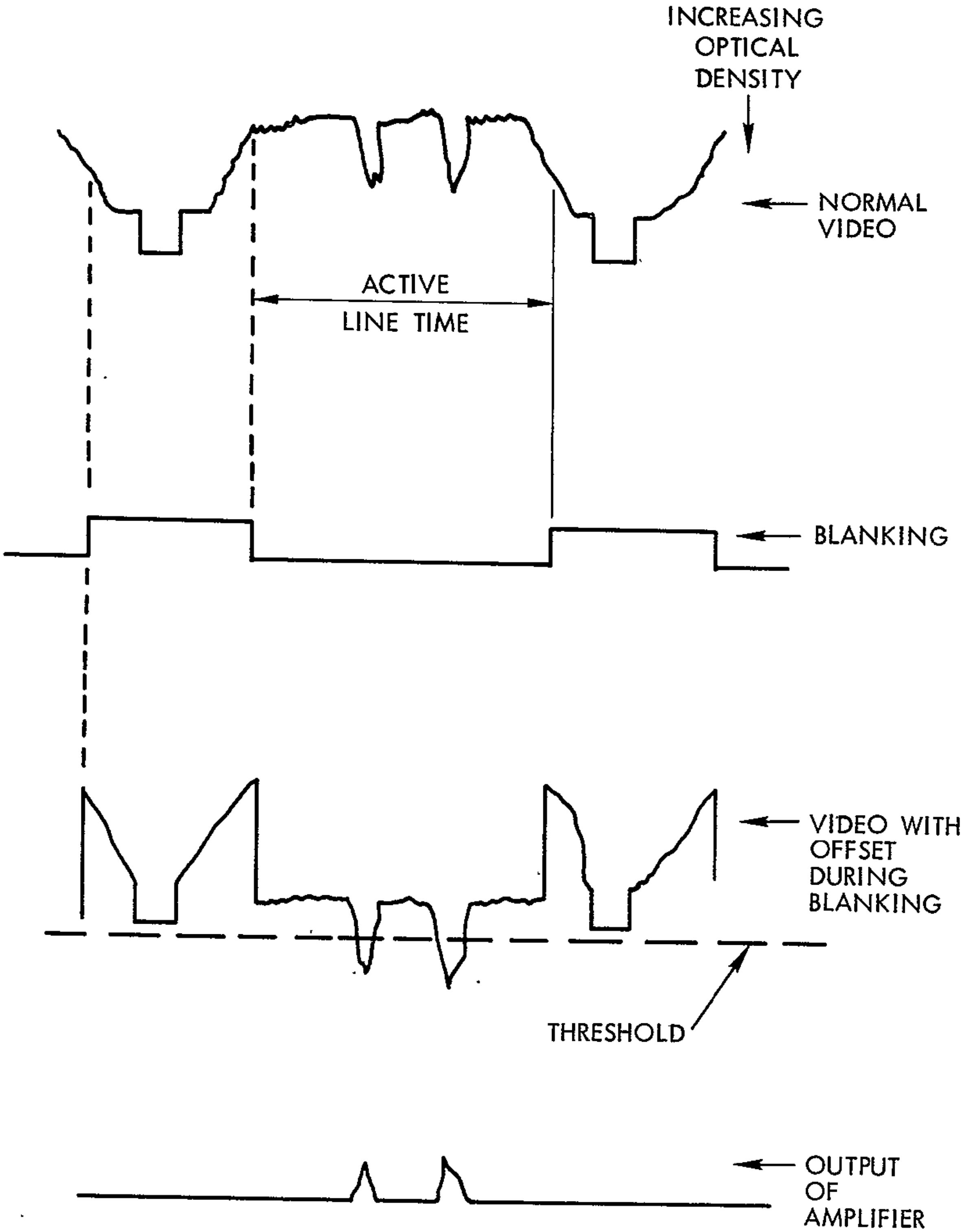


Figure 5-7 IOD Waveforms

SECTION VI

INTERACTIVE GRAYSCALE DISPLAY

A. SYSTEM DESCRIPTION

The CALMS Grayscale Display is a system to present computer processed digital pictorial information visually via a closed circuit TV monitor and to provide the man-machine communication medium for identifying displayed data locations for interactive processing requirements.

Figure 6-1 is the block diagram of the Grayscale system. The computer interfacing, direct memory access (DMA) control and the grayscale control logic is located in the CALMS system's extension mounting box. The DMA control logic is a DR11-B system unit. The computer interfacing and grayscale control logic is implemented in a BB11 system unit utilizing an M1710 Unibus Foundation card and three special cards. This logic interfaces to the computer, the DMA control logic, the scan converter interface logic and the operator's cursor control logic. The scan converter interface logic and the cursor control logic are located in a rack mounted unit just below the system's scan converter in the assembly called the Operator System Control Module.

The Grayscale system stores and displays picture data elements (pixels) in a 1024 x 1024 matrix array. The entire array is scanned for display (Read). For storing (Write) the array is random addressable. The data is stored by specifying the array line, starting pixel number and the number of sequential pixel positions to be written into. The array may be erased either totally (Clear) or partially (Selective Erase). Selective erasing is accomplished on a per line basis, as in writing pixels. The use of Selective Erase is limited by its resolution, as erasure of a line affects the information stored in up to two lines on either side of the one being erased.

The Grayscale's cursor can be positioned by either the operator or the computer to identify a pixel location in the displayed array. The cursor is a crosshair superimposed on the scan converter's video output and is, therefore, non-destructive to the image data stored within the scan converter. The cursor's digital X-Y position is available to the computer in two device address registers.

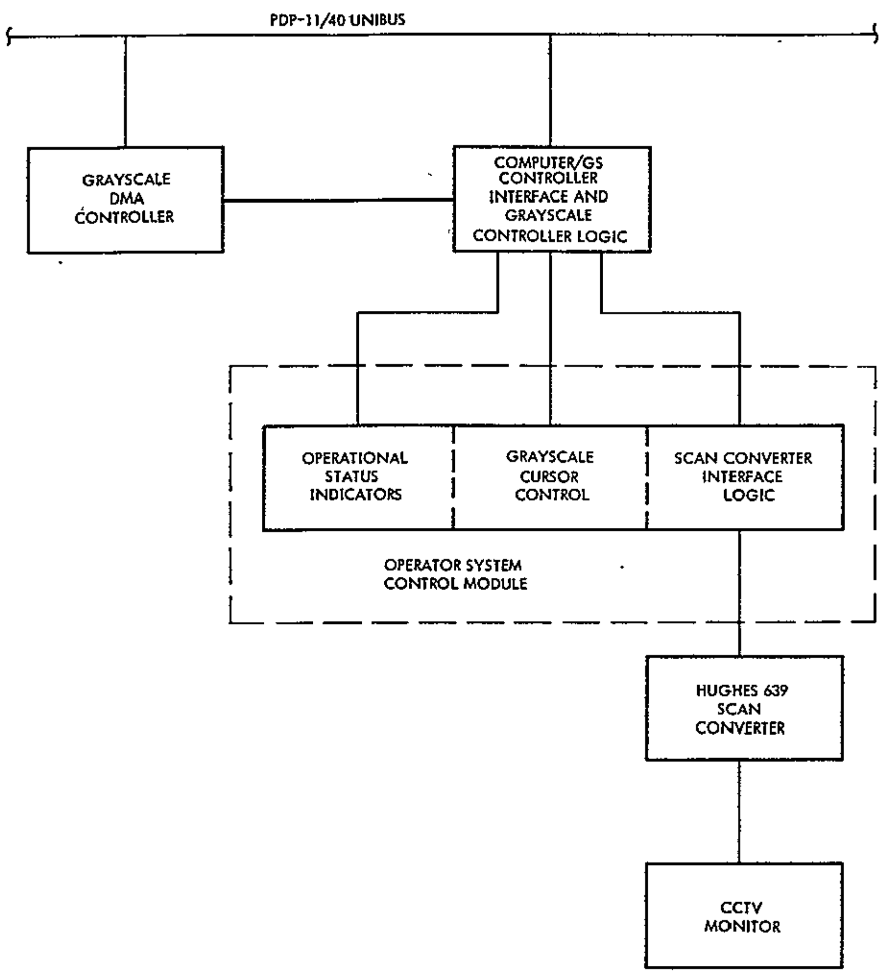


Figure 6-1 CALMS Grayscale System Block Diagram

Specifications

Pixel Writing Rate: 250,000 pixels/second

Line Writing Rate: 17 milliseconds/line, 1-1024 pixels

Writing Linearity: Less than ± 1% of full scale deflection

Gray Levels: At least 10 distinctly visible logarithmic gray levels

Image Retention: A stored image can be displayed for a minimum of 20 minutes without noticeable fading.

Selective Erase Rate: 17 milliseconds/line, 1-1024 pixel locations

Time to Clear: 67 milliseconds

Cursor Resolution: ± 3 pixel positions

Cursor Linearity: ± 2% of full scale deflection

B. INTERFACING REQUIREMENTS

1. Hardware

The DR11-B supplies its own interface circuitry to the PDP-11 Unibus. There is no additional wiring required to be done to the grayscale system's DR11-B as the Device Address and Interrupt Vector Address used are the ones to which the unit is wired when delivered.

The interface between the PDP-11 Unibus and the control logic is implemented by the M1710 Unibus Interface Foundation card. The Device Addresses and Interrupt Vector Addresses are set by the proper jumpering on the card. The desired Bus Request level line must be wired from the M1710 card connector to the Unibus connector on the BB11 and the matching Bus Grant line broken and run from the Unibus connector through the M1710 card connector slot on the BB11.

The control logic is connected to the DMA control unit by short cables. The control logic is connected to the indicator unit and the scan converter interface and operator cursor control unit by cables. The cables' high speed signal lines are differentially driven twisted pairs and the low speed lines are open collector driven single lines with resistor termination on the signal receiver ends.

The Hughes 639 Scan Converter is connected to the scan converter interface logic as prescribed in the Hughes Model 639 Scan Conversion Memory Instruction Manual.

2. Software

The definitions of the Device Address Registers associated with the Grayscale system appear at the end of this section. Unless noted, a true condition is a 1.

Figure 6-2 shows the operations required to initialize the Grayscale system for a Write, Selective Erase or Selective Erase/Write operation. The initialization and starting of these operations is under the control of the computer.

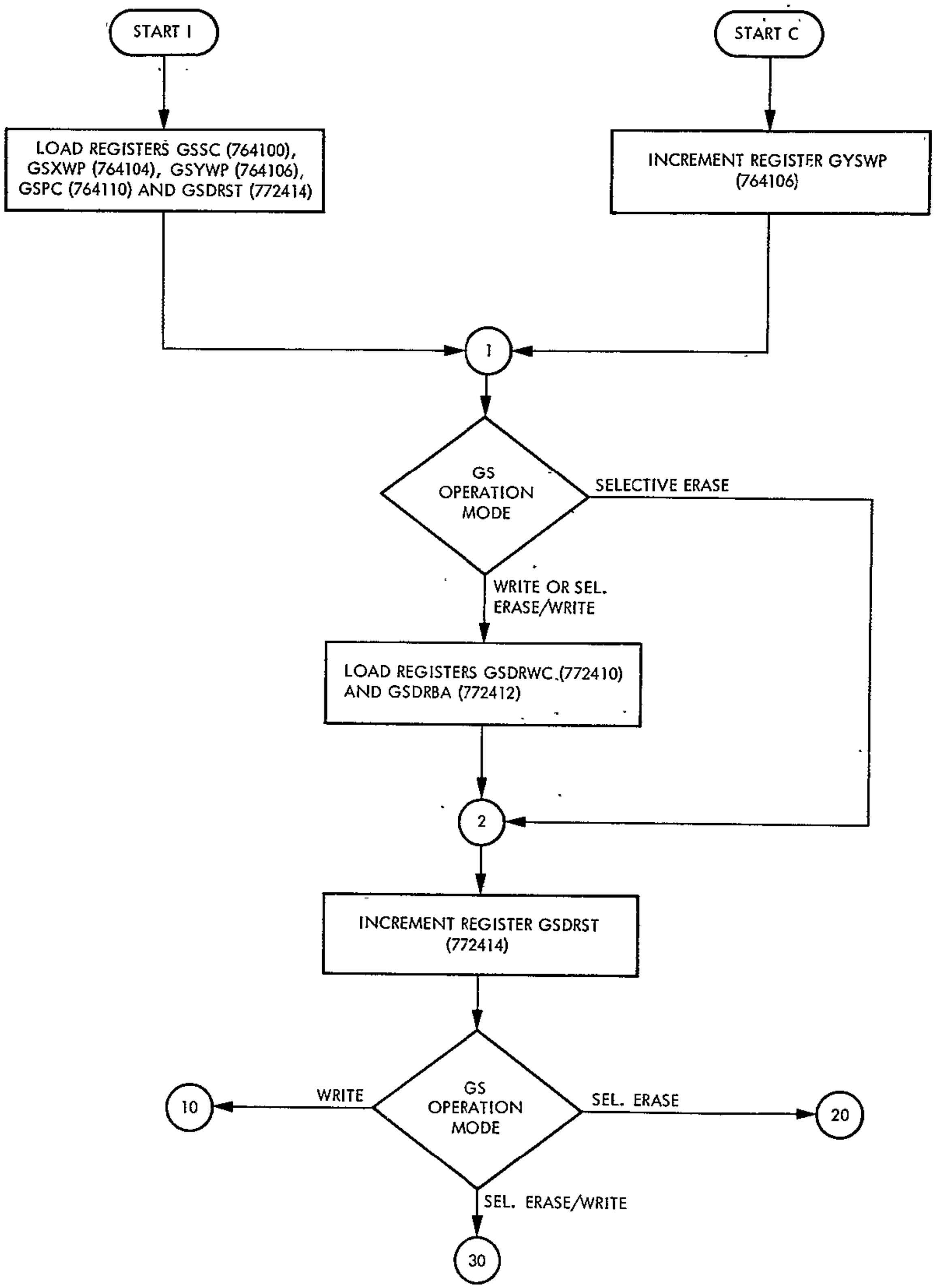


Figure 6-2 CALMS Grayscale Input Operations Initialization Flow Diagram

Start I is the entry point when beginning an operation involving a block (or array) of sequential grayscale lines. (The array must be rectangular. That is, the array is contiguous, equal length lines.) The indicated registers may be loaded in any sequence. They are loaded by the computer program with the following information:

GSSC Register: The register controls the operation of the Grayscale Controller. Bits 1-4 should be set as required to perform the desired Grayscale operation.

GSXWP Register: This register is loaded with the 10 bit binary position number (0-1023) of the first pixel to be erased and/or written in a Grayscale line during the operation.

GSPC Register: This register is loaded with the 10 bit 2's complement binary value of the number of sequential pixels (0-1023) to be erased and/or written in a Grayscale line during the operation.

GSYWP Register: This register is loaded with the 10 bit binary value (0-1023) of the lowest line number of the array to be erased and/or written during the operation.

As was noted, all of the three preceding registers are 10 bits in length. Any attempt to load them with a number greater than 1023 will result in a modulo 1024 being loaded and the resultant Grayscale storage area being operated on. Also, the sum of the true values of the contents of the GSXWP and GSPC registers should not exceed 1023.

GSDRST Register: This register controls the operation of the GS DMA Controller. When initializing the Grayscale system for a Write or Selective Erase/Write operation, the following information should be loaded:

Bits 4 & 5: The two most significant bus address bits of the DMA data source area in memory. The DMA controller does not increment these bits. Therefore, the DMA data source area must not cross these bits' boundaries.

Bit 6: Set to a 1 if a DMA Operation Complete interrupt is required.

Bit 8: Set to a 1 for the initial DMA transfer request.

For a Grayscale Erase operations, bits 6 and 8 should be set to 0.

Start C is the entry point to initiate the operations on the lines succeeding the first line of the array. All that is required is the incrementing of the value of GSYWP.

If the operation being initialized is a Write or Selective Erase/Write, the GSDRWC and GSDRBA registers are loaded with the count of the number of pixel words to be transferred and the 16 least significant bits of the bus address of the first pixel word, respectively.

The GSDRST register is incremented to start the Grayscale operation.

The procedure just described is the recommended one for an operation involving a rectangular array. This is not the only procedure that would perform the required operation. For instance, the GSYWP register could be loaded with the highest line number at Start I and the register could be decremented at Start C. Also, the branch at node 1 for Selective Erase is not necessary. The loading of registers GSDRWC and GSDRBA would just be superfluous operations.

For an operation on an array that is not rectangular, the operation must be performed by initializing via Start I for each line and/or by dividing the array into rectangular subarrays.

The programmer has some options in the way the pixel data can be formatted for writing to the Grayscale system. The 16 bit words in the pixel DMA source area may contain either 1 or 2 pixels of information. In the 1 pixel per word format, the data must be in the Pixel Byte A position. In the 2 pixels per word format, the data is written into the Grayscale system in the Byte A-Byte B order. During the operation initialization, bit 4 of register GSSC must be set to reflect the format of the pixel DMA source data.

There is also the programming option to have each pixel byte written once or written and replicated in the horizontally adjacent pixel position. This operation is controlled by bit 3 on the GSSC register.

The GSPC and GSDRWC registers should be loaded with the following relationships:

GSSC 4	BITS 3	GSPC	GSDRWC
0	0	N	N/2
0	1	N	N/4
1	0	N	N
1	1	N	N/2

where N is the number of pixel positions being operated upon in a line.

The CYCLE bit (bit 8) of GSDRST should be set to initiate a DMA request when GO is sent (increment GSDRST).

The entire disp1av mav be cleared by incrementing register GSSC.

If register GSYWP is incremented past 1024, a vertical "wrap-around" operation will be performed. Likewise, if the sum of the contents of GSXWP and the 2's complement of GSPC is greater than 1023, a horizontal wrap-around will occur.

The Grayscale system's control logic generates an Operation Complete interrupt request when it finishes an operation on a line. For this request to generate an interrupt to the computer, its enable bit on register GSIRE must be set to a 1 by the computer.

The Grayscale system's cursor may be positioned and controlled by either the computer or the operator. The source of the cursor's control is determined by the computer through bit 8 of register GSSC. When under computer control, the cursor is always on. Its position is determined via registers GSXCP and GSYCP. It's Constant/Flashing state is controlled via bit 7 of register GSSC. The cursor element is a crosshair. Bit 6 of GSSC will control the Crosshair/Dot element state if and when the dot mode is available and is deemed desirable.

The operational status indicators are controlled via registers OSID and OSND. OSID is the individual light indicator register. A lamp is turned on/off by setting/resetting its bit in OSID. OSND is used to load the various numeric indicators. To display a decimal number in one of the displays, the binary value of the number and the display's binary code is loaded into the register. The maximum value is $2^9 -1$.

C. THEORY OF OPERATION

Figure 6-1 is an overall block diagram of the Grayscale display system. The functions of the component blocks are as follows:

Grayscale DMA Controller: This is a DEC DR11-B DMA Control system unit. It controls the DMA transfers of the picture element (pixel) intensity information from the computer to the Hughes 639 Scan Converter via the Grayscale Controller Logic.

Computer/GS Controller Interface and GS Controller Logic: This unit provides the handshaking with the computer and circuits to control the output to the Hughes 639 and to the Operational Status Indicators.

Scan Converter Interface: These are circuits that provide the D/A conversion and control signal buffering to the Hughes 639 Scan Converter.

Hughes 639 Scan Converter: This is a device that accepts and stores image data at verious rates and outputs the information as a standard video signal to a CCTV monitor. The device also has a zoom feature and non-destructive cursor.

CCTV Monitor: A standard RETMA rate, 1029 line resolution TV monitor.

Operational Status Indicators: Front panel lights and numeric displays that indicate the status of computer operations being performed. The indicators are located on the Operator System Control panel. The indicator unit is physically part of but functionally separate from the Grayscale system.

Elementary Theory of Operation

For all computer/Grayscale system operations, except the interrupt, the Grayscale system is the bus slave. The DMA Control unit (DR11-B) provides the necessary handshaking and buffering for the GSDRWC, GSDRBA, GSDRST and GSDRDB registers. All other computer handshaking and buffering is provided by the M1710 card.

<u>Data Transfer, Computer to GS Controller Device Address Register (DAR)</u>: The M1710 card decodes the Unibus address lines and control lines. If the address code is one of the GS Controller's DAR's the M1710 generates a strobe to it, causing the data to be transferred. (All write DAR inputs are daisy-chain connected to the Unibus data lines via the receiver-buffers on the M1710.) All transfers are word transfers.

<u>Data Transfer, GS DAR to Computer</u>: The M1710 card decodes the Unibus address lines and control lines. If the address code is one of the GS Controller DAR's the M1710 generates a strobe that places the DAR's contents onto the Unibus data lines. (All read DAR outputs are bussed together through tri-state gates and, in turn, to the Unibus data lines via the data line drivers on the M1710.)

<u>Write, Selective Erase and Selective Erase/Write Operations</u>: These are operations by which the computer can add or delete data in the scan converter's storage medium. After the various registers have been loaded as described in the Software section and a GO has been generated by incrementing register GSDRST, the Grayscale Controller takes charge of the operation.

When the GO is generated the operation control bits (bits 1 and 2 of register GSSC) are decoded and the controller's microprogram is entered at the appropriate address. Figure 6-3 depicts the flow of a Write operation. When the GS Controller's microprogram is entered the Grayscale's busy signal is set and a Write operation enabled. The controller awaits the GS Vertical Read Gate signal from the scan converter. (This signal signifies the beginning of the scan converter's Read mode vertical retrace blanking. It is used as a 60 cycle sync to start a Selective Erase and/or Write mode operation.) When received, the GS Controller loads its X and ΔX (pixel number) counters from their respective registers, loads the first pixel data (intensity) word from the DMA Controller, signals the DMA Controller to initiate the transfer from memory of the next pixel data word and signals the scan converter to switch to Write mode. The GS Controller now awaits the fall of the Mode Switching Delay signal from the scan converter. (This signal rises whenever the scan converter is commanded into another operating mode. It falls when the scan converter has settled into

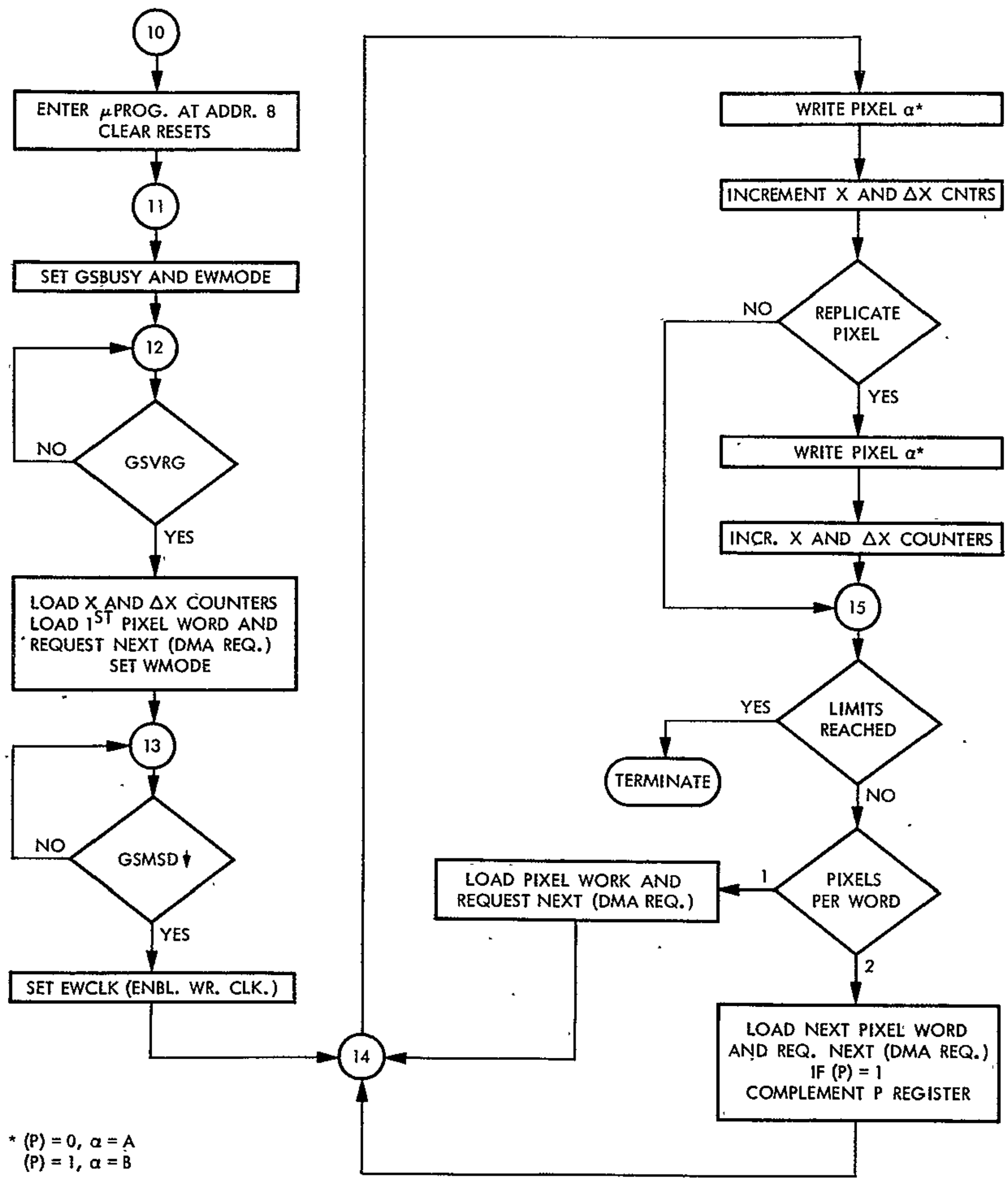


Figure 6-3 CALMS Grayscale Write Operation Flow Diagram

the commanded mode.) When received, the GS Controller turns on its Write clock and begins to transfer the pixel data from the computer memory into the scan converter. The operation flow from here on depends on whether 1 or 2 pixel data bytes are packed in a pixel data word and whether or not the pixel data is to be replicated. After each pixel write operation, the X and ΔX counters are incremented. When either counter is incremented to 1024 the limits have been reached and the GS Controller terminates the operation.

The Selective Erase operations (Fig. 6-4) are performed in a similar fashion as the Write with the following exceptions:

1. There is no transferring of pixel data words.
2. The microprogram entry point and the flow exit is determined by whether the operation is a Selective Erase or a Selective Erase/Write.
3. The Erase Unblank is a constant rather than a pulsed signal as is Write Unblank

The above operations are terminated by the GS Controller as shown in Fig. 6-4. The GS Controller resets itself and sends the Operation Complete Interrupt Request. By this action the scan converter will be signaled back to Read mode the next time its Read vertical deflection is in its retrace blanking state.

Due to the fact that the scan converter is switched to Write or Selective Erase mode at the beginning of vertical retrace and switched to Read mode at any time during vertical retrace, a Write or Selective Erase operation that takes somewhat less than this time (typically 1.2 milliseconds) will not cause flicker on the Grayscale system's TV monitor.

Detailed Theory of Operation

Hughes Model 639 Scan Conversion Memory: The detailed information in contained in the Hughes Model 639 Instruction Manual.

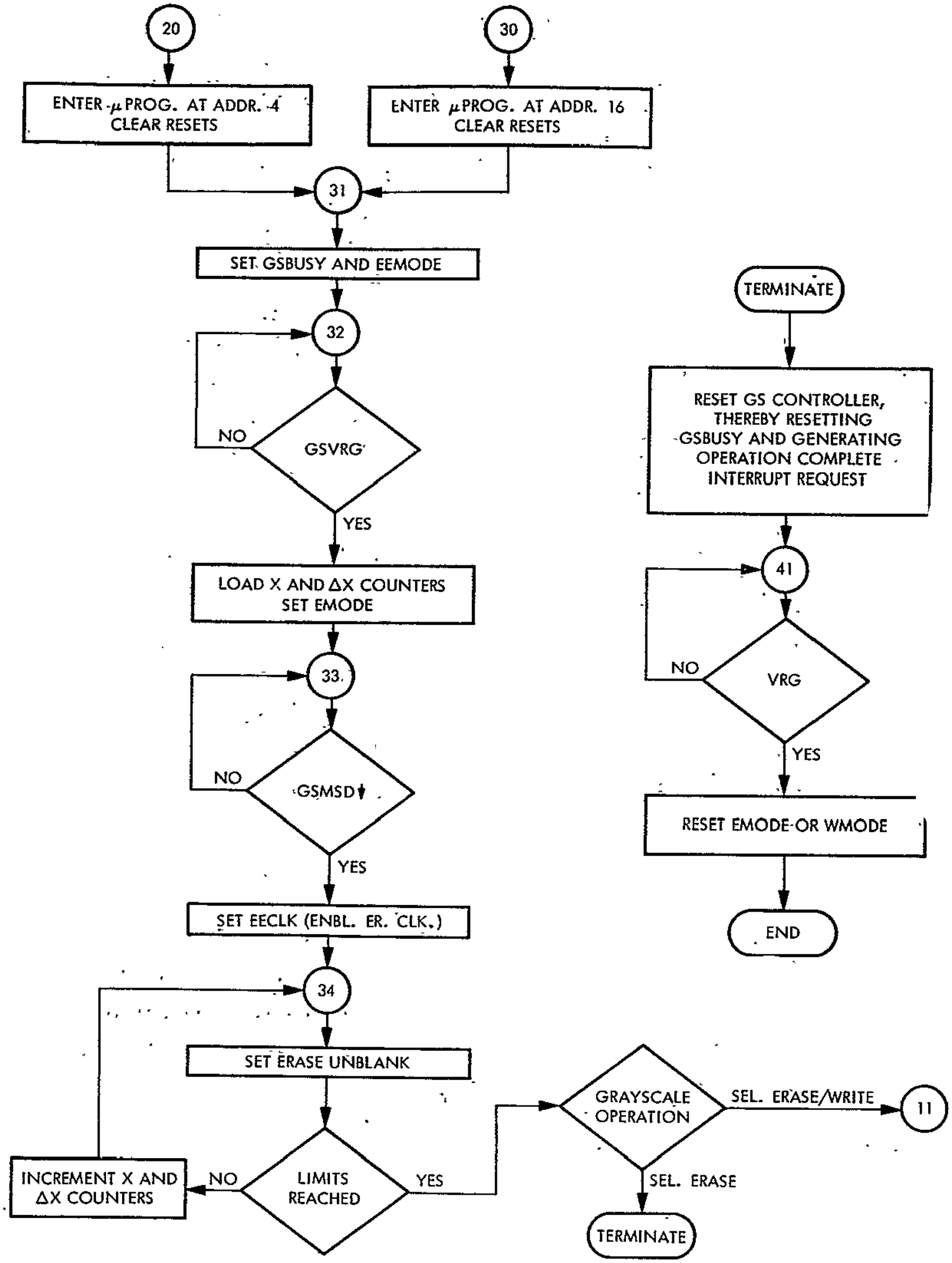


Figure 6-4 CALMS Grayscale Selective Erase Operations and Termination Flow Diagrams

Grayscale DMA Controller: The detailed information is contained in the Digital Equipment Corporation DR11-B Manual and DR11-B Engineering Drawings.

Viewed as a "black-box" the DMA Controller is initialized by the computer with the starting address of the memory area associated with the transfer, the number of words (16 bits) to be transferred and various control bits. The DMA Controller signals the GS Controller that a DMA operation has been initiated by sending it a GO signal (caused by the computer incrementing the DMA Controller's GSDRST register). At this time, the DMA Controller requests the transfer of the first word from memory (bit 8 of GSDRST having been set by the program). The GS Controller sends a CYCLE REQUEST signal for all succeeding transfers. The DMA Controller performs the required operations to effect the transfers, incrementing its address register and decrementing its word count after each transfer. When the word count is exhausted, the DMA Controller will be disabled. If so enabled, it will send an operation complete interrupt to the computer.

The DMA Controller's user signals are connected as shown on JPL drawing "CALMS Grayscale C1, Sheet 2.'

Grayscale Controller

Figure 6-5 lists the cards that comprise the Grayscale Controller and depicts their layout within the DEC BB11 system unit. The following is a detailed description of each card and any special requirements or procedures:

Grayscale Microprocessor Card (C1): This card (as well as cards C2 and C3) is a DEC OEM card. It contains the JPL designed GS Controller microprocessor, scan converter operating mode and unblanking control circuits, the statu and control register GSSC, the pixel data buffer register, the pixel byte multiplexer, the differential drivers to the Scan Converter Interface for the pixel bits and control signals and the DMA Controller user signal terminations

Cursor and Display Circuits (C2): Implemented on this card are the indicator registers OSID and OSND and their decoding and driving circuits to the Operator Control Module's Indicator unit, the GS Controller's Write and Erase clock circuits and the cursor position registers GSXCP and GSYCP.

	A	B	C–F	
4	UNIBUS CONNECTOR (OUT)		M1710 INTERFACE FOUNDATION CARD (C4)	4
3	POWER		POSITION REGISTERS AND INT. ENABLE CKTS. (C3)	3
2	(RESERVED)		CURSOR AND DISPLAY CIRCUITS (C2)	2
1	UNIBUS CONNECTOR (IN)		GRAYSCALE M PROCESSOR CARD (C1)	1
	A	B	C D E F	

PIN SIDE

Figure 6-5 CALMS Grayscale Controller Card Layout (DEC BB11 System Unit)

Position Registers and Interrupt Enable Circuits (C3): This card contains the X write starting position register GSXWP, the Y write position register GSYWP, the X pixel count register GSPC, the X and ΔX counters, the limits circuit, the X and Y Write/Cursor position multiplexers, the X and Y differential drivers to the Scan Converter Interface unit and the interrupt enable register GSIRE.

M1710 Interface Foundation Card (C4): This is a DEC card that provides the circuits for communication between the computer and the GS Controller. The card also has space for OEM circuits in which is implemented the GS Controller's interrupt circuits and Device Address Register (DAR) gating circuits.

The computer handshaking operations ofthe M1710 card are explained in detail in the various DEC M1710 manuals. There is, however, some special wiring that is done on an M1710 card to configure it as a unique device on the Unibus. One such operation is to define the base device address.

The M1710 is capable of decoding 16 DAR codes. The address codes are consecutive Unibus word addresses, the lowest being the base address. To define this address, the buffered Unibus address bits 5-12 must be appropriately wired, true or complement, to the decoding logic gate E38 of DEC drawing M1710-0-1, Sheet 2. The base address wiring for the GS Controller is shown on JPL drawing "CALMS Grayscale C4."

When the M1710 decodes a Unibus address assigned to it, it enables a select line SEL N, where N is the octal device address relative to the M1710's base device address. The select signal is combined with the decoded output of the two Unibus control lines, C0 and C1, to generate a strobe signal to the associate DAR. The strobes generated are SEL N IN H for data transfers from the GC Controller to the computer and SEL N OUTLO H for data transfers from the computer to the GS Controller. The strobe circuits are implemented on the OEM portion of the M1710 card (JPL drawing CALMS Grayscale C4).

The M1710 generates the required handshaking signals for computer interrupt operation. The special wiring required is listed on JPL drawing CALMS Grayscale C4. Part of this special wiring is the defining of the Interrupt Vector Address.

The Interrupt Vector Address is defined on bits 2-8, all other bits being zero (i.e., false). As the GS Controller has 8 possibleinterrupt requests, bits 2-4 are defined by the priority circuit for the specific interrupt requests and bits 5-8 are defined by hard wiring. (At present the only interrupt request being used in the GS Controller Operation Complete.) The priority arbitration logic operates as follows:

1. An interrupt request signal gates its bit in the interrupt request register. If that request is enables, its bit will be set true.

2. When the interrupt request register is non-zero, the priority circuit will create the vector address bits 2-4 for the true request with the highest priority and initiate the Interrupt Request Strobe.

3. The INT REQ STROBE gates the vestor bits 2-4 into the vector bit register and initiates action in the M1710 interrupt circuit, which performs the

required handshaking with the computer.

4. At the end of the interrupt cycle (INTR DONE), the vector bits 2-4 are decoded to reset the requesting bit in the interrupt request register.

5. If at the fall of INTR DONE another bit is true in the interrupt request register, the operation will repeat, starting at step 2.

Grayscale Cursor: The cursor is a white crosshair element superimposed by the scan converter on the video to the TV monitor. The cursor may be turned on or off, made to flash or remain steady, and positioned by circuits in the GS Controller. The GS Controller cursor circuits can accept commands from either the computer or the operator. Which source the commands are accepted from is controlled by the computer via bit 8 on the GSSC register.

Whenever the computer is in control, the cursor is always on. The constant/flashing state is controlled through bit 7 of the GSSC register. The cursor's position is controlled by the computer's control of the GSXCP and GSYCP registers.

When the operator has control (so indicated by the green light on the Operator System Control panel), the cursor's on/or and constant/flashing states are controlled by front panel switches. The cursor's position is controlled by the operator incrementing/decrementing the GSXCP and GSYCP registers by use of the cursor joystick on the Operator System Control panel. The joystick is a rate device. That is, the further it is deflected from its rest position, the faster the cursor will be deflected in the indicated direction. Whenever the joystick is released, it returns to its rest position and the cursor remains where it was positioned.

The cursor control and position data is sent to the scan converter only when it is in Read mode.

Operational Status Indicators: These are computer controlled Operator System Control panel displays of two types, lights and decimal numeric displays.

The lights are controlled by corresponding bits on register OSID. The numeric displays are controlled by register OSND and logic within the GS Controller.

Register OSND contains the value to be displayed in binary and the binary code of the display. The binary value is sent to the Indicator unit in the Operator System Control module where it is converted to 3 BCD digits which are in turn fed to the data inputs of all of the numeric displays. Whenever OSND is loaded by the computer, the GS Controller decodes the display number and strobes the BCD data into the corresponding display.

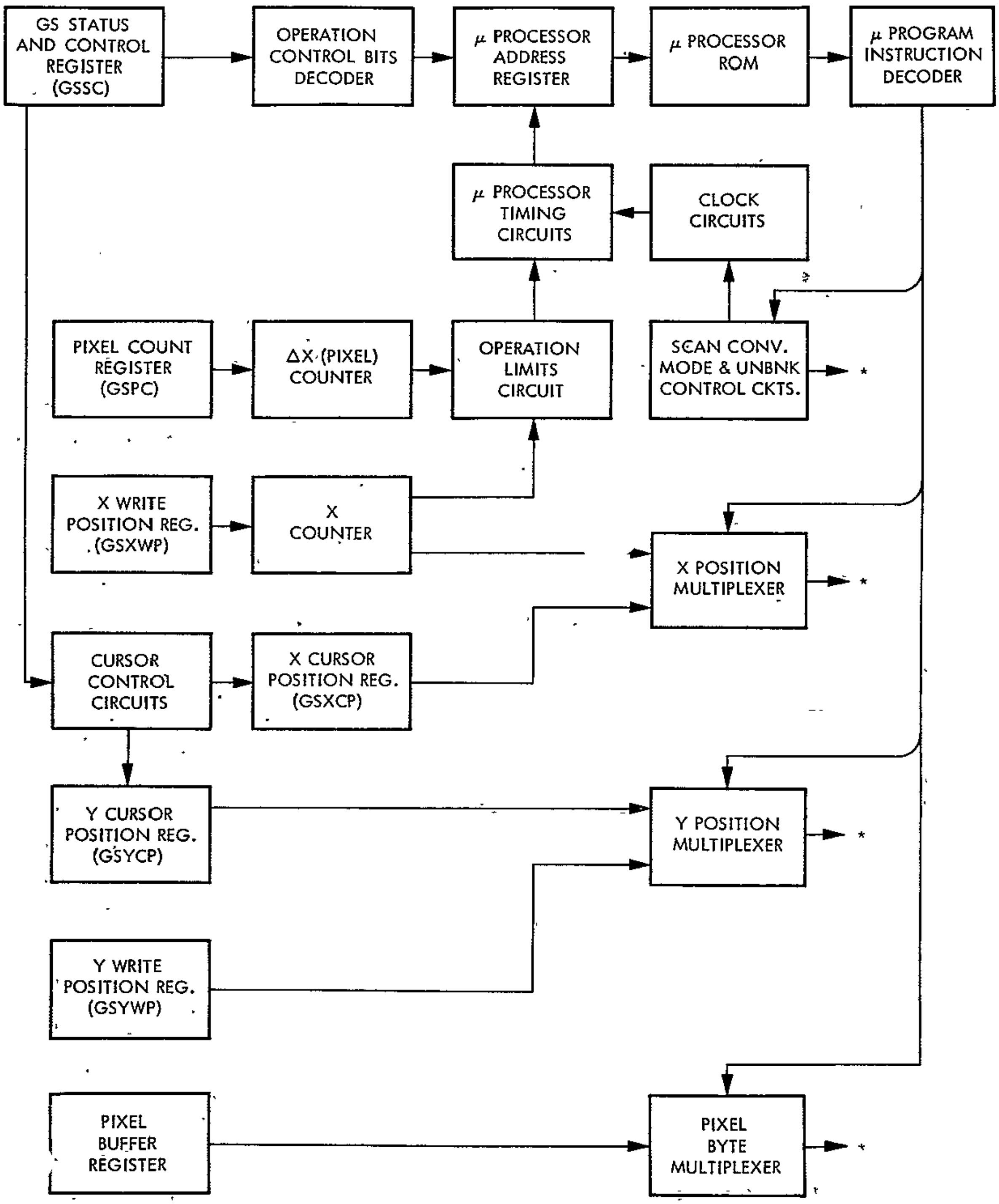
Grayscale Controller Operations: Figure 6-6 is the functional block diagram of the GS Controller, exclusive of the computer handshaking and interrupt circuits. Figures 6-7 through 6-13 are timing diagrams of various phases of GS Controller operations.

The microprocessor consists of two SN74193 up/down counters for the address register, an SN74188 ROM, instruction decoding circuits and timing circuits. Figure 6-14 shows the coding of the ROM program. Figure 6-15 lists the microprocessor codes and their descriptions.

Figure 6-16 lists the GS Controller signals and their definitions.

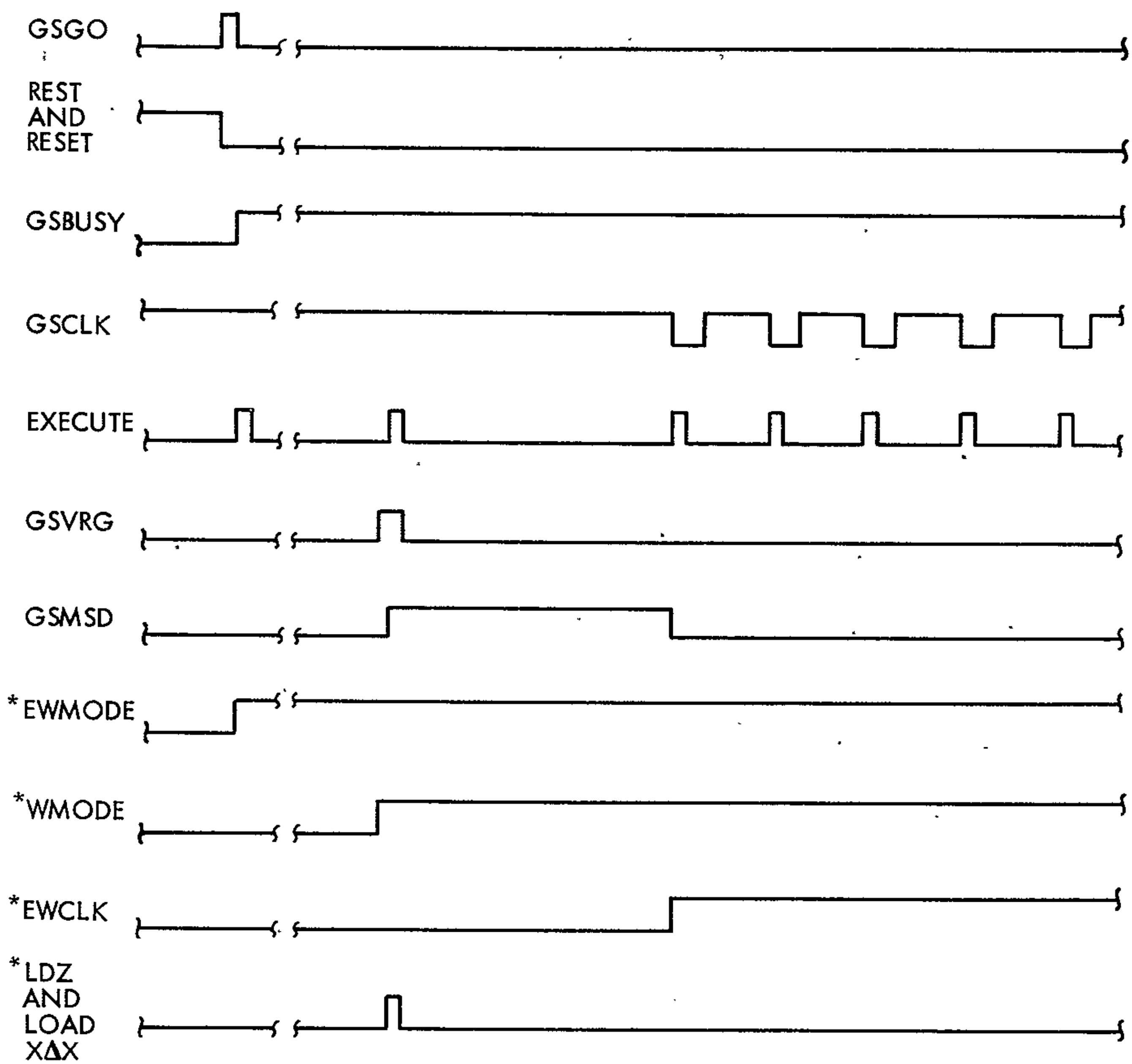
Operator System Control Module: Figure 6-17 is the layout of the Operator System Control module. It contains three units of the Grayscale system, the Operational Status Indicator circuits, the Grayscale Cursor Control circuits and the Scan Converter Interface logic.

The Operational Status Indicator circuits are shown on JPL drawing "Operator System Control Module, Sheet 2." There are gates that receive the individual-lamp signals from the GS Controller's OSID register and drive the lights on the module's front panel. The numeric display circuits receive the binary display value from the GS Controller's OSND register, converts it to 3 BCD digits and outputs them to the Hewlett-Packard numeric indicators on the module's front panel. The H-P indicators can store the BCD data. The loading strobes are the outputs of the display number decoder in the GS Controller. These signals are



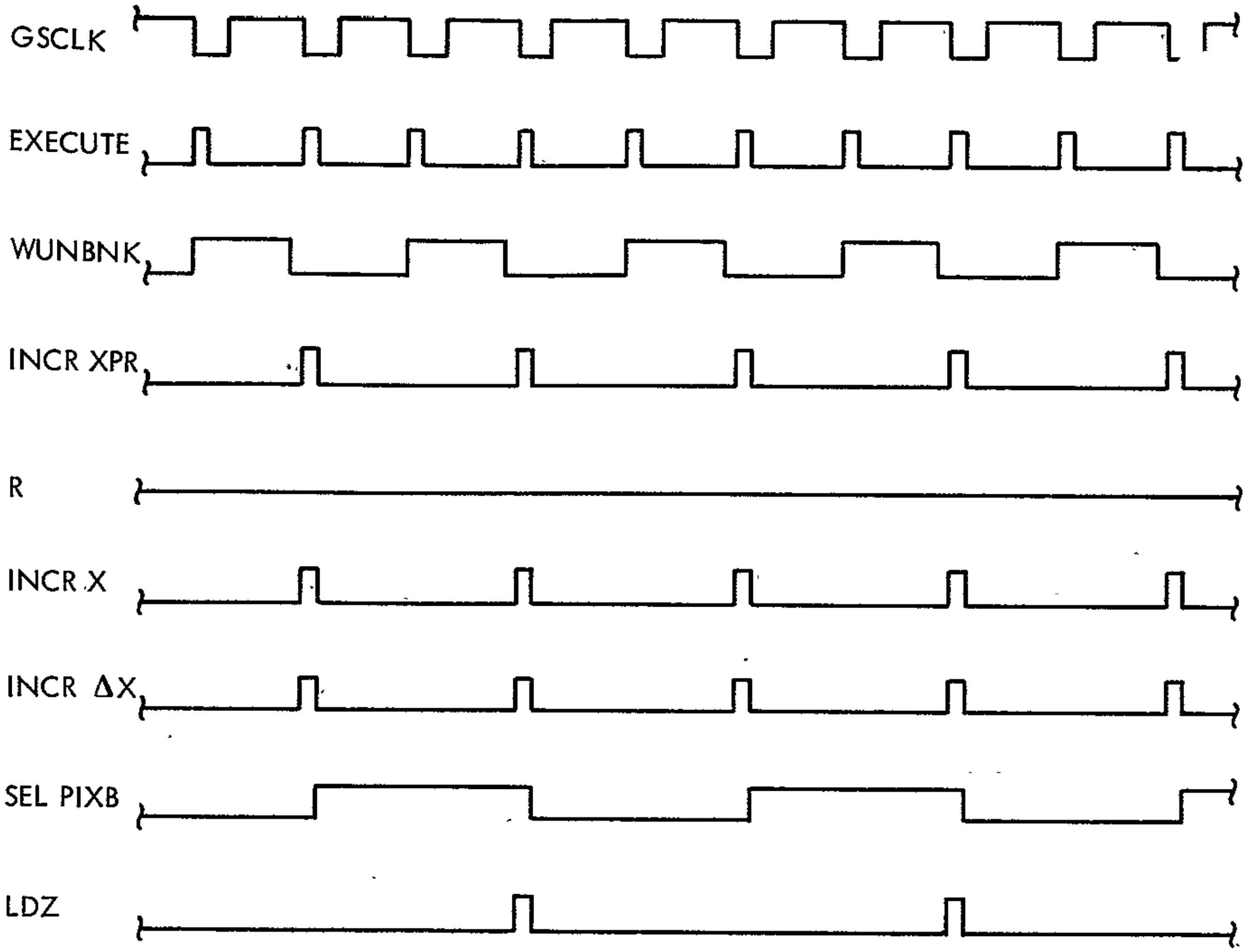
*TO SCAN CONVERTER INTERFACE

Figure 6-6 CALMS Grayscale Controller Block Diagram



*FOR SELECTIVE ERASE AND SELECTIVE ERASE/WRITE OPERATIONS SUBSTITUTE EEMODE, EMODE AND EECLK, AND ELIMINATE LDZ

Figure 6-7 CALMS Grayscale Write Mode Initialization Timing Diagram

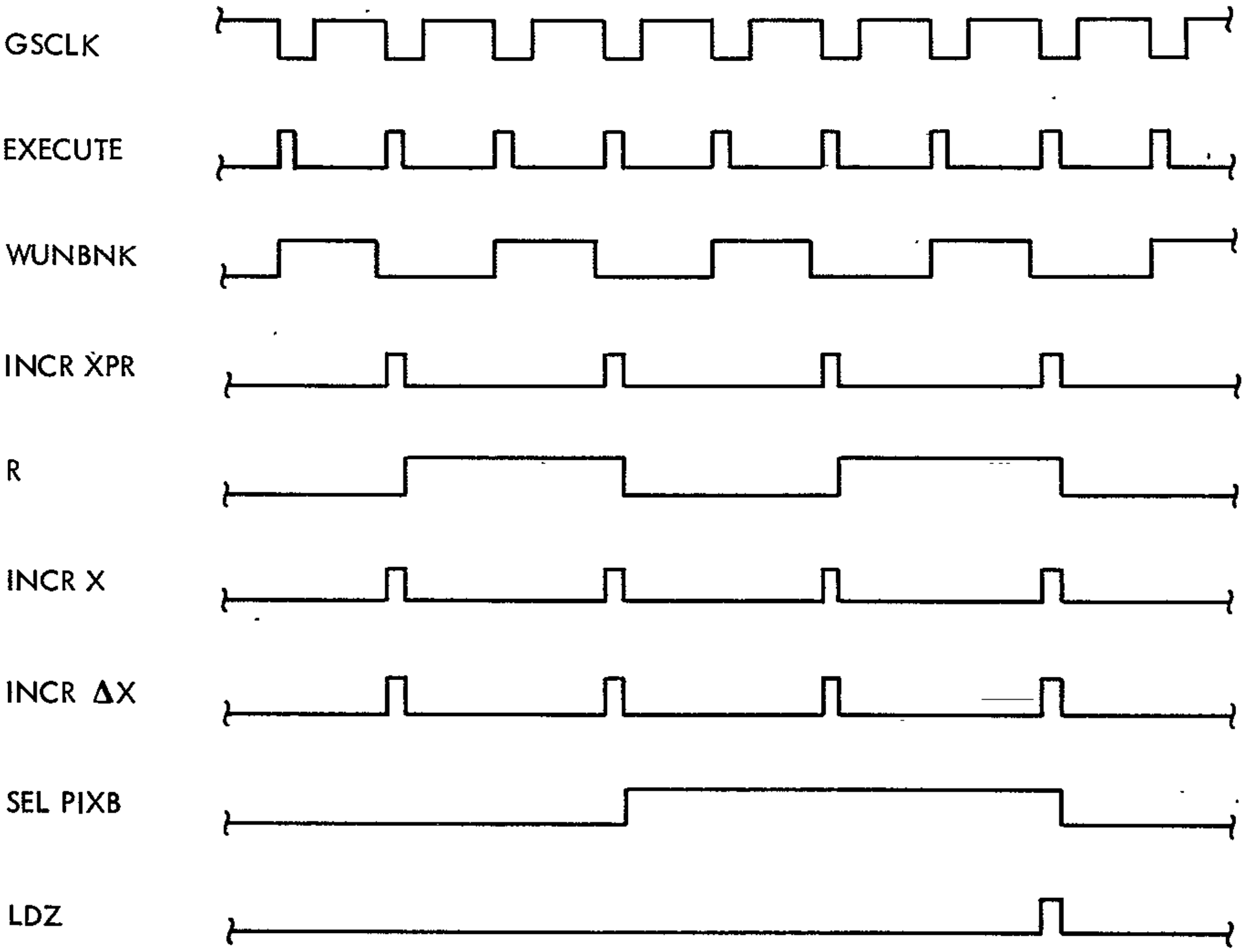


PIXREP = FALSE (DON'T REPLICATE PIXELS)

PIXWD = FALSE (2 PIXELS/WORD)

LIMITS = FALSE

Figure 6-8 CALMS Grayscale Write Mode Operation Timing Diagram

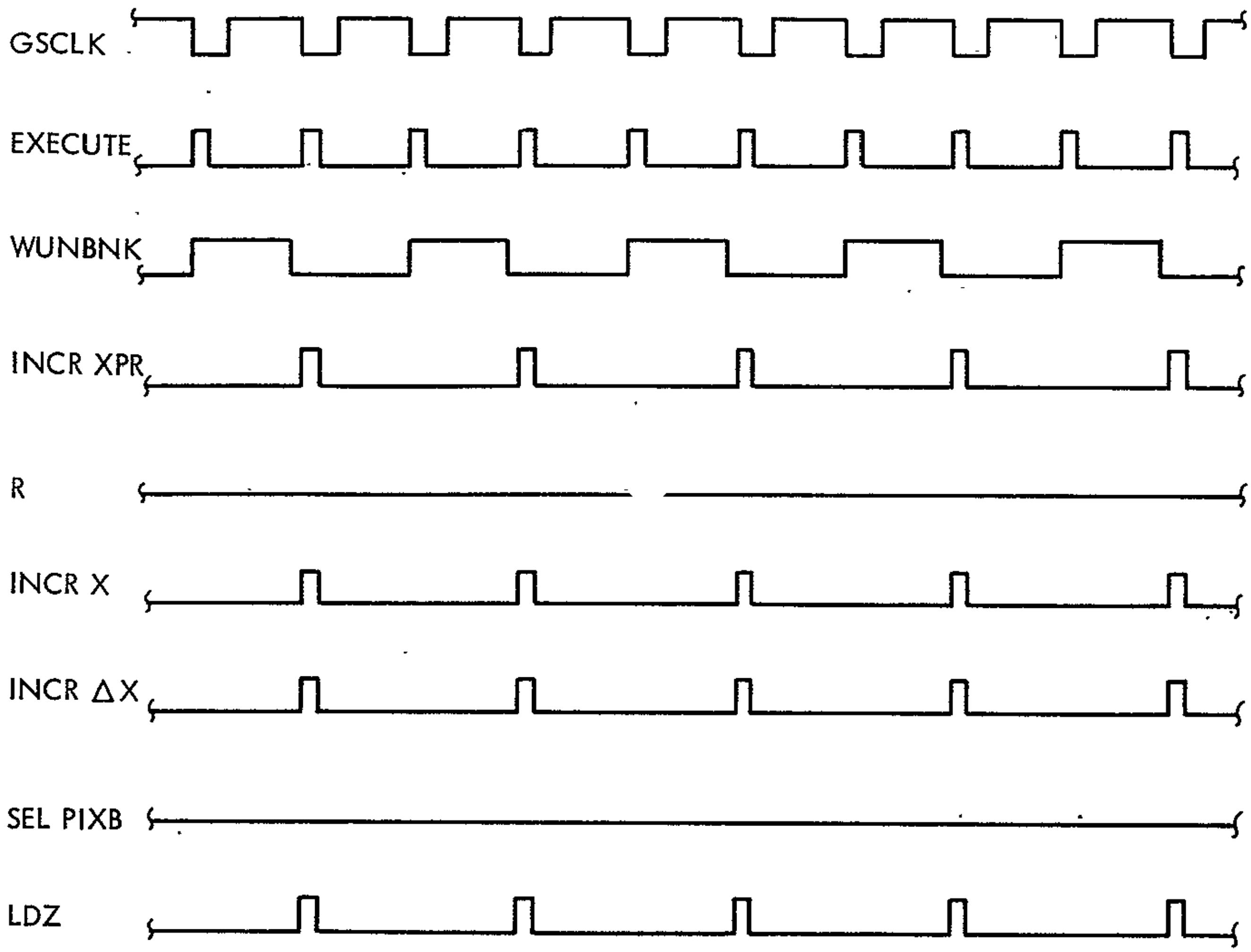


PIXREP = TRUE (REPLICATE PIXELS)

PIXWD = FALSE (2 PIXELS/WORD)

LIMITS = FALSE

Figure 6-9 CALMS Grayscale Write Mode Operation Timing Diagram

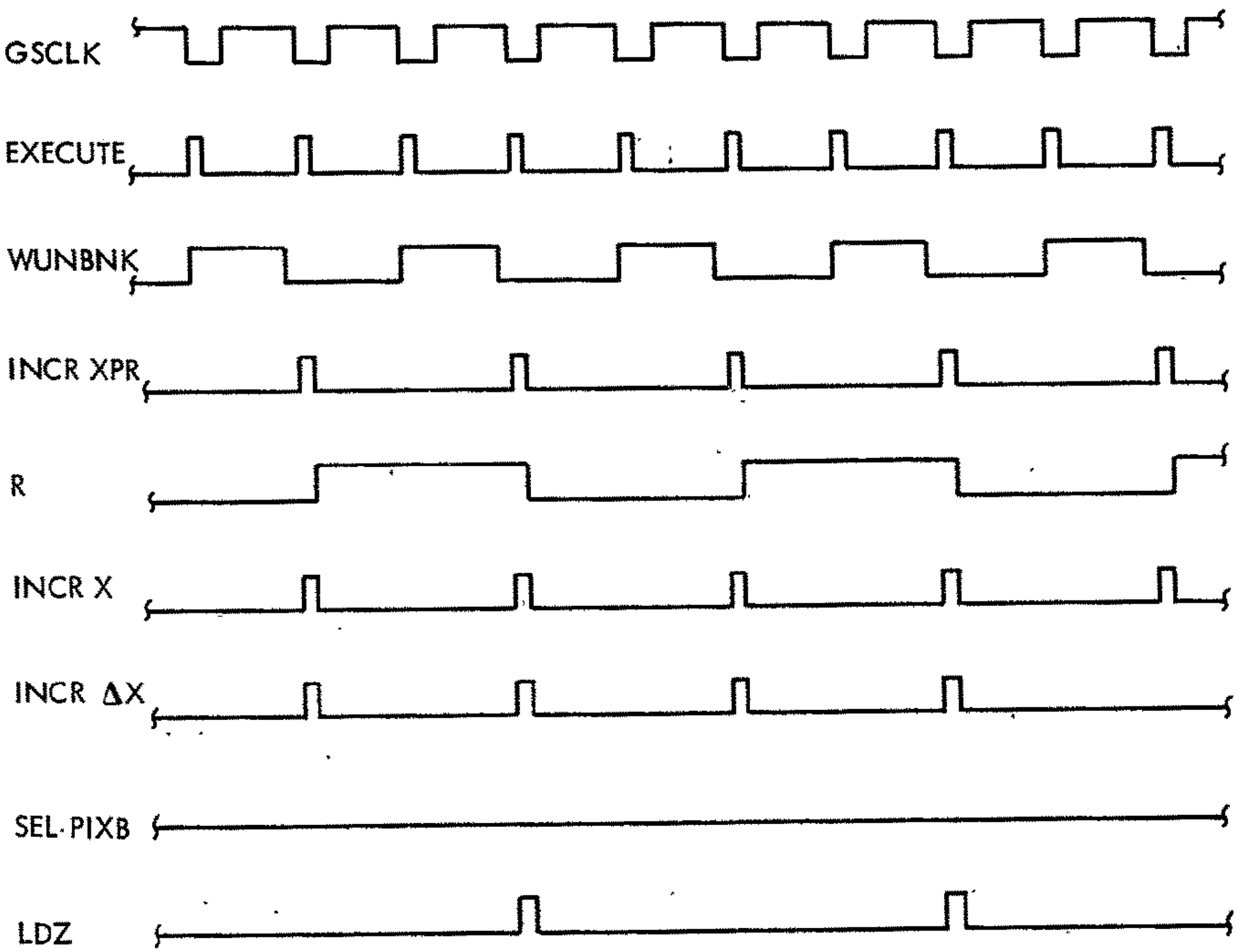


PIXREP = FALSE (DON'T REPLICATE PIXELS)

PIXWD = TRUE (1 PIXEL/WORD)

LIMITS = FALSE

Figure 6-10 CALMS Grayscale Write Mode Operation Timing Diagram



PIXREP = TRUE (REPLICATE PIXELS)

PIXWD = TRUE (1 PIXEL/WORD)

LIMITS = FALSE

Figure 6-11 CALMS Grayscale Write Mode Operation Timing Diagram

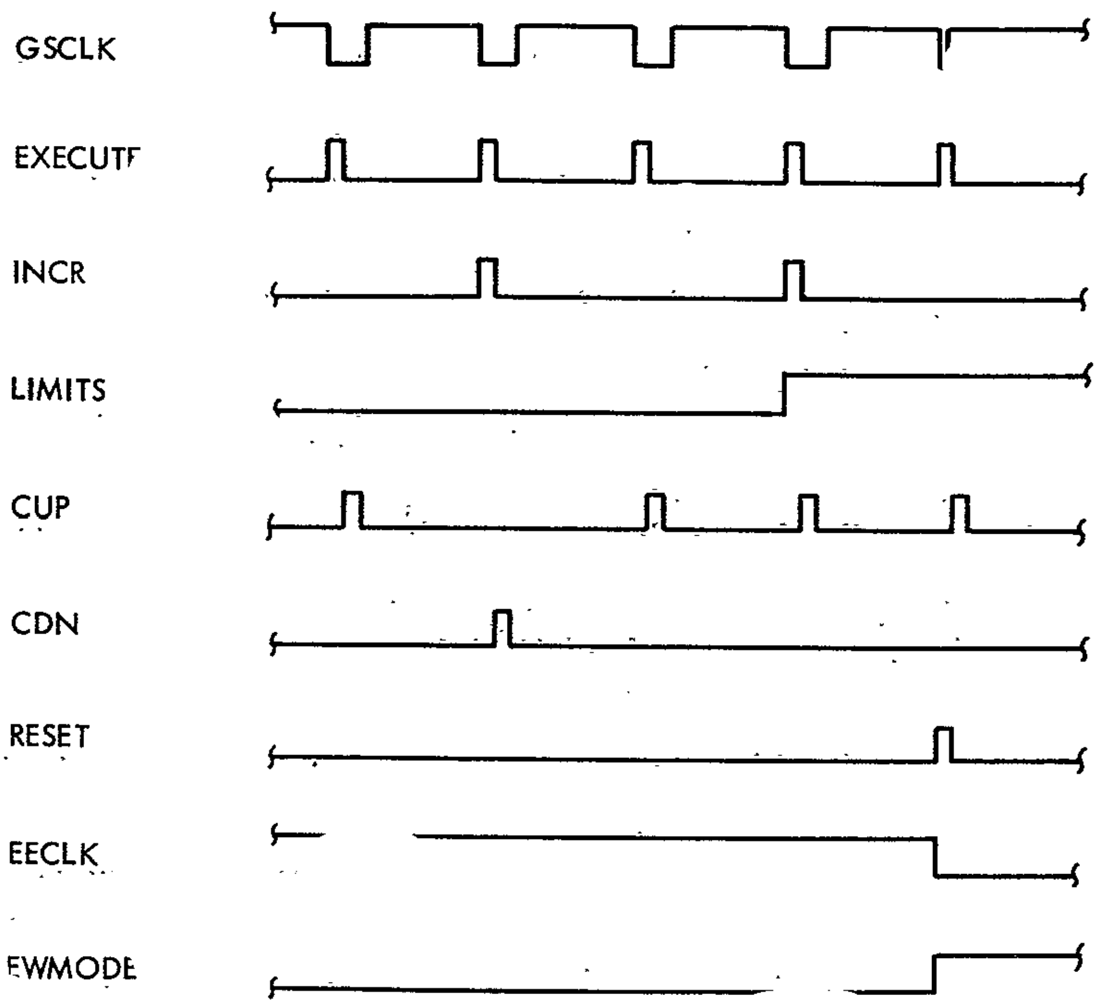


Figure 6-12 CALMS Grayscale Erase/Write Operation Transition Timing Diagram

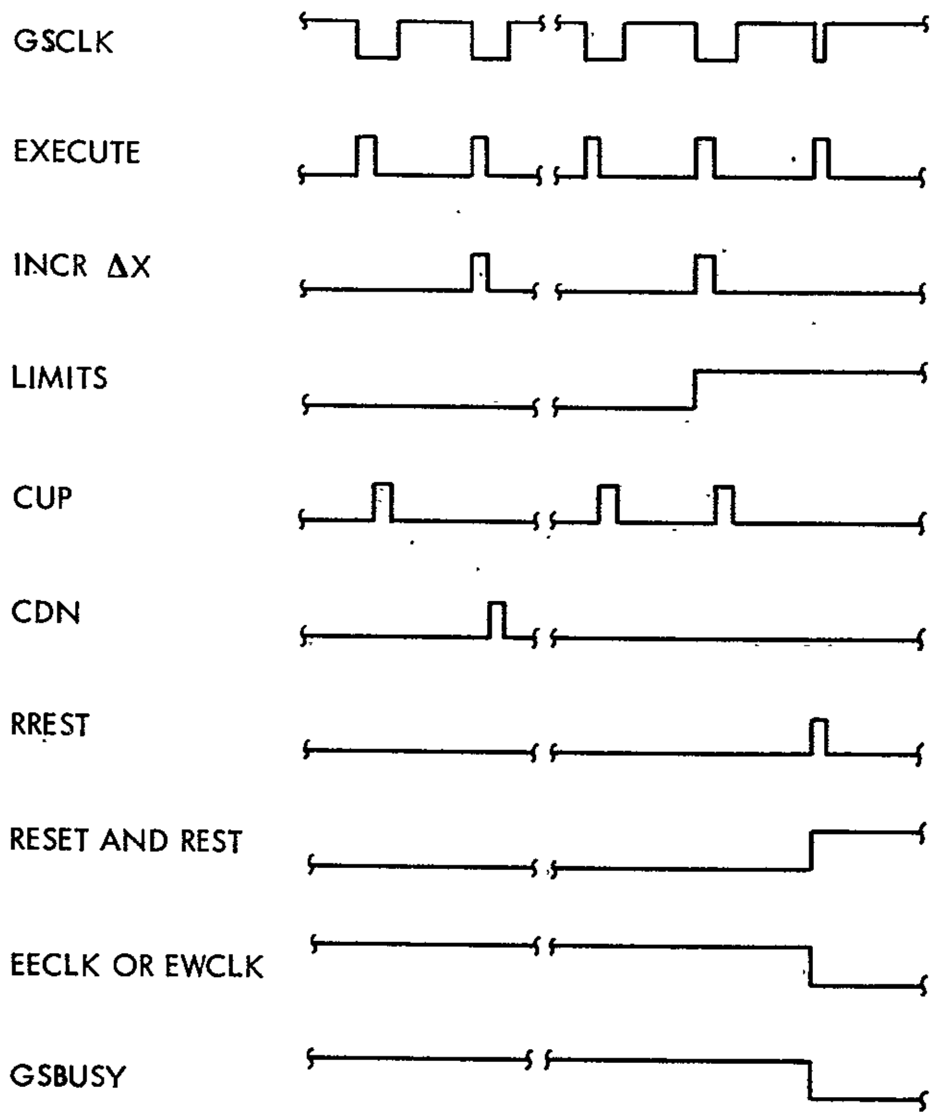


Figure 6-13 CALMS Grayscale Erase/Write Operation Termination Timing Diagram

ADDR	CODE 7 6 5 4 3 2 1 0	DEC1	HEX	REMARKS
0	0 0 0 0 0 0 0 0		00	"Rest" Position (From INIT Signal)
1				
2				
3				
4	0 0 0 0 1 0 0 1		09	Enable Erase Mode & Erase Clock
5	1 0 0 0 0 0 0 1		81	Load X &ΔX Counters
6	1 0 0 0 1 0 0 0		88	Unblank
7	1 0 1 0 0 1 0 0		A4	Incr X &ΔX Counters, Incr/Decr μProg Addr Reg.
8	0 0 0 0 0 1 0 1		05	Enable Write Mode & Write Clock
9	1 0 0 0 0 0 1 1		83	Load X &ΔX Cntrs, Z Reg. & Request DMA XFER
10	1 0 0 0 1 0 0 0		88	Unblank
11	1 0 1 1 0 0 0 0		B0	Incr X, ΔX, P&R, Cond. LDZ, Incr/Decr μProg Addr
12	0 0 0 0 0 0 0 0		00	Stop
13				
14				
15				
16	0 0 0 0 1 0 1 1		0B	Enable Erase Mode & Erase Clock
17	1 0 0 0 0 0 0 1		81	Load X &ΔX Counters
18	1 0 0 0 1 0 0 0		88	Unblank
19	1 0 1 0 0 1 0 0		A4	Incr X &ΔX Counters, Incr/Decr μProg Addr Reg.
20	0 0 0 0 0 0 0 0		00	Stop
21				
22				
23				
24				
25				
26				
27				
28				
29				
30				
31				

Figure 6-14 CALMS Grayscale Controller ROM Coding Sheet

Bit 7 = 0 "ENABLE" Op Codes

BIT	ACTION
6	(no op)
5	1 = Set DOWN for microprogram address decrement
4	(no op)
3	1 = Set EEMODE, 0 = Reset EEMODE
2	1 = Set EWMODE, 0 = Reset EWMODE
1	(no op)
0	1 = Set Grayscale BUSY, 0 = Reset Grayscale BUSY

Bit 7 = - "OPERATE" Op Codes

BIT	ACTION
6	(no op)
5	1 = Set DOWN for microprogram address decrement
4	1 = Increment X, ΔX, P & R. LDZ IF R=1 or PIXREP L.
3	1 = Unblank Grayscale Enable
2	1 = Increment X & ΔX counters. Increment/decrement microprocessor address register.
1	1 = Load Z (pixel) register and request DMA
0	1 = Load X & ΔX counters

Figure 6-15 Grayscale Microprocessor Codes

BCD #	BCD Bit #, where # is 0 to 2: Binary code bits of the numeric display numbers.
CDN	Count Down: Decrementing pulse for the microprocessor's address register.
CUP	Count Up: Incrementing pulse for the microprocessor's address register.
CURSOR DOT	Cursor Dot: True enables cursor dot element. Flase enables cursor crosshair element. Not implemented at present.
CURSOR FLASH	Cursor Flash: Computer cursor control signal. Causes cursor to flash when in the Computer Cursor mode.
DISP #	Display Bit #, where # is 00 to 11: Binary value bits of the numeric data to the decimal numeric indicators in the Operator System Control module.
ECLK	Erase Clock: GS Controller erase mode operation clock.
EECLK	Enable Erase Clock: Signal that turns on the GS Controller to begin an erase mode operation on the scan converter at the next 60 cycle sync pulse. Set EEMODE = IRB3 · $\overline{\text{IRB7}}$ · EXECUTE Reset EEMODE = $\overline{\text{IRB3}}$ · $\overline{\text{IRB7}}$ · EXECUTE + REST
EMODE	Erase Mode: GS Controller generated signal to the scan converter to command it to its erase mode.
ENBL IR#	Enable Interrupt Request #, where # is 00 to 11: Outputs of register GSIRE used to allow the interrupt requests to generate interrupt to the computer.
EWCLK	Enable Write Clock: Signal that turns on the GS Controller clock used in write mode operations.
EWMODE	Enable Write Mode: Signal that enables the GS Controller to begin a write mode operation on the scan converter at the next 60 cycle sync pulse. Set EWMODE = IRB2 · $\overline{\text{IRB7}}$ · EXECUTE Reset EWMODE = $\overline{\text{IRB2}}$ · $\overline{\text{IRB7}}$ · EXECUTE + REST

Figure 6-16 Grayscale Controller Signals

EXECUTE	Execute: Signal that decodes and performs the microprocessor instructions.
GO	Go: Signal from the DMA Controller to start a GS Controller operation.
GS BUSY	Grayscale Bush: Signal that indicates the GS Controller is is performing on erase and/or write operation on the scan converter. This signal blocks any further commands to the GS Controller until the current operation is complete. Set GS BUSY = IRBO · $\overline{\text{IRB7}}$ · EXECUTE Reset GS BUSY = $\overline{\text{IRBO}}$ · $\overline{\text{IRB7}}$ · EXECUTE + REST
GSCLK	Grayscale Clock: The OR function of the two GS Controller Clocks. GSCLK = WCLK + ECLK
GSGO	Grayscale Go: Start signal for a GS Controller operation. GSGO = GO · $\overline{\text{GS BUSY}}$
GSINIT	Grayscale Initialize: GSINIT = INIT + OUT 14 · SEL 0 OUTLO
GSMSD	Grayscale Mode Switching Delay: A signal generated by the scan converter when it is in the transition period of switching between operating modes.
GS OPER COMP INT	Grayscale Operation Complete Interrupt Request: A request for an interrupt to the computer to signify that a GS Controller operation has been completed.
GS PIXEL #	Grayscale Pixel Intensity Bit #, where # is 0 to 5.
GS UNBNK	Grayscale Unblank: GS Controller generated unblanking signal to the scan converter.
GSVRG	Grayscale Vertical Read Gate: A 1 microsecond signal initiated by the rise of VRG. It is used as a 60 cycle sync.
IB #	Indicator Bit #, where # is 00 to 15: The individual lamp control bits to the Indicator unit in the Operator System Control module.

Figure 6-16 Grayscale Controller Signals (contd)

IN	In: Signal generated by the M1710 when a Bus Master input operation is in progress.
IN #	Date In Bit #, where # is 00 to 15: Buffered and bussed Unibus data lines for transfers from the GS Controller.
INCR ΔX	Increment Delta X: Signal to increment the ΔX counter. INCR ΔX = INCR XPR + PINCR XΔX
INCR XPR	Increment, X, ΔX, P and R Registers: Microprocessor instruction that increments the X and ΔX counters and that acts as the clock to the pixel byte control circuit (P) and the pixel replicate control circuit (R). INCR XPR = IRB7 · IRB4 · EXECUTE
INIT	Initialize: Computer generated initialization signal used to preset the GS Controller.
INTR DONE	Interrupt Done: Signal from the M1710 interrupt circuit signifying the completion of an interrupt operation.
IRB #	Instruction ROM Bit #, where # is 0 to 7: Outputs of the microprocessor's ROM.
LDISP #	Load Display #, where # is 0 to 5: Decoded display number signal used to lead a numeric display.
LDZ	Load Z: Signal that loads the pixel data word from the DMA Controller and requests the next DMA transfer.
LIMITS	Limits: Signal that indicates that the requested number of pixel poxitionshave been operated on by the GS Controller or that the X position for an operation is greater than 1023. LIMITS = PC > 1023 + XW > 1024
LOAD XΔX	Load X and ΔX Counters: Signal that loads the X and ΔX counters from the GSXWP and GSPC registers, respectively.
OCURSOR	Operator Cursor = $\overline{\text{Computer Cursor}}$: When true the operator may control the cursor.
OMODE1, OMODE2	Operating Mode Control Bits: GS Controller control code signals generated by the computer.

Figure 6-16 Grayscale Controller Signals (contd)

OUT #	Data Out Bit #, where # is 00 to 15: Buffered and ubssed Unibus data lines for transfers to the GS Controller.
OUT LOW	Out Low Byte: Signal generated by the M1710 when a Bus Master output operation is in progress involving either a word or a low order byte transfer. (All transfers to the GS Controller are word transfers.)
PANEL PRIME	Panel Prime: Front panel pushbutton generated signal that clears the entire scan converter storage area.
PC > 1023	Pixel Count Greater than 1023: Pixel Counter overflow bit.
PINCR XΔX	Program Increment X and ΔX Counters: Microprocessor instruction that increments the X and ΔX counters. PINCR XΔX = IRB7 · IRB2 · EXECUTE
PIXREP	Pixel Replicate: True causes a double erasing and/or writing of each pixel during a scan converter input operation.
PIXWD	Pixel per Word: True = 1 pixel byte per DMA word. Flase = 2 pixel bytes per DMA word.
PLDZ	Program Load Z: Microprocessor instruction that generates LDZ PLDZ = IRB7 · IRB1 · EXECUTE
PRIME TGT	Prime Target: Command to the scan converter to perform a CLEAR operation (full storage area clear).
PRIME TGT DLY	Prime Target Delay: Pulse initiated by PRIME TGT to allow for the time it takes the scan converter to perform a full target CLEAR operation.
REQ1, REQ2	Request 1, Request 2: Inputs to the M1710 interrupt circuit to start a computer interrupt operation. The two inputs are wired together.
RESET IR #	Reset Interrupt Request #, where # is 00 to 07: Reset signal for bit # in the Interrupt Request register on M1710. Active on completion of the interrupt cycle initiated by Interrupt Request #.

Figure 6-16 Grayscale Controller Signals (contd)

RMODE — Read Mode: This GS Controller used signal indicates that the scan converter is not being commanded by the GS Controller in its write or erase mode.

$$RMODE = \overline{EMODE} \cdot \overline{WMODE}$$

RREST — R Reset: Microprocessor generated GS Controller reset signal.

$$RREST = \overline{IRB7} \cdot \overline{IRB1} \cdot EXECUTE$$

SEL # — Select #, where # is the octal Grayscale Controller DAR address relative to the base GS Controller DAR address: Signal generatec by the M1710 when a GS Controller DAR is being addressed by the computer.

SEL # IN — Select # In: Strobe generated on the M1710 to place DAR #'s data onto the Unibus data lines.

SEL # IN = SEL # · IN

SEL # OUTLO — Select # Out: Strobe generated on the M1710 to load DAR # from the Unibus data lines.

SEL # OUTLO = SEL # · OUTLO

SEL PIXB — Select Pixel B: Control signal for the pixel byte multiplexer circuit. True = output byte B. False = output byte A.

UNBNK — Unblank: Microprocessor instruction that initiates an unblanking signal to the scan converter.

UNBNK = IRB7 · IRB3 · EXECUTE

VECTOR BIT # — Interrupt Vector Address Bit #, where # is 02 to 08: Bits defining the interrupt vector access for a Grayscale interr operation.

VRG — Vertical Read Gate: A scan converter generated signal that is true when the scan converter read deflection is in vertical retrace.

WCLK — Write Clock: GS Controller write mode operation clock.

WMODE — Write Mode: GS Controller generated signal to the scan converter to command it to its write mode.

Figure 6-16 Grayscale Controller Signals (contd)

X #	X Position Bit #, where # is 00 to 09: Output of the X position multiplexer. X # = XW# + XC#
XC#	X Cursor Bit #, where # is 00 to 09: Bits of register GSXCP that define the digital value of the cursor position in the X (horizontal) direction.
XDN	X Down: Register GSXCP decrement pulse from the cursor joystick.
XUP	X Up: Register GSXCP increment pulse from the cursor joystick.
XW#	X Write Position Bit #, where # is 00 to 09: Output of the X position counter that defines the pixel position in the horizontal direction during an erase or write mode operation.
XW > 1023	X Write Position Greater than 1023: X position counter overflow bit.
Y #	Y Position Bit #, where # is 00 to 09: Output of the Y position multiplexer. Y # = YW # + YC #
YC #	Y Cursor Bit #, where # is 00 to 09: Bits of register GSYCP that define the digital value of the cursor position in the Y (vertical) direction.
YDN	Y Down: Register GSYCP decrement pulse from the cursor joystick.
YUP	Y Up: Register GSYCP increment pulse from the cursor joystick.
YW #	Y Write Position Bit #, where # is 00 to 09: Output of register GSYWP that defines the pixel position in the vertical direction during an erase or write mode operation.

Note: The H or L suffix to a signal name denotes the voltage level at which the signal is true. H = TTL + voltage and L = 0 volts.

Figure 6-16 Grayscale Controller Signals (contd)

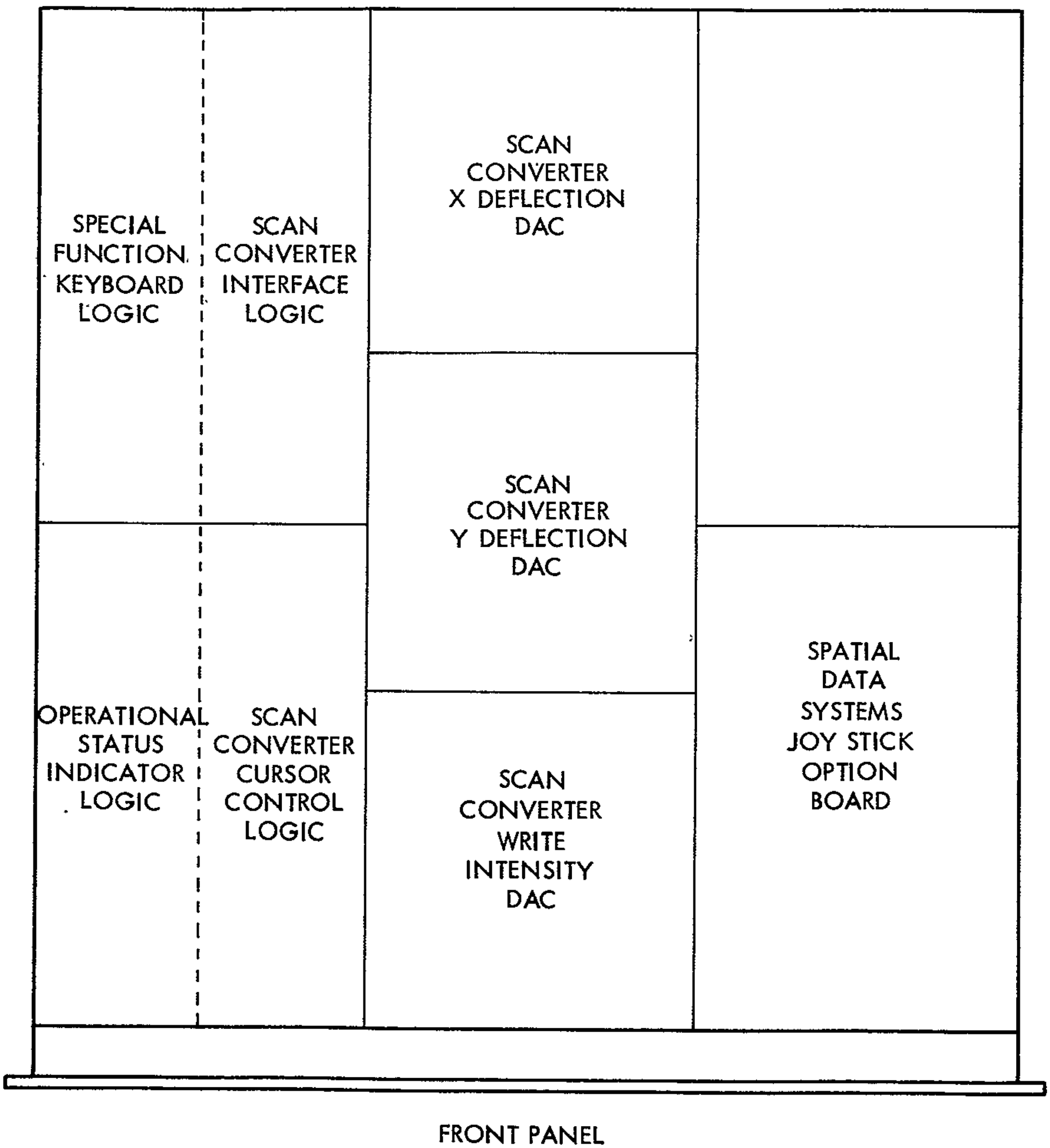


Figure 6-17 Operator System Control Module Layout Top View

differentially transmitted to the indicator circuit where they are transformed to logic levels and sent to their respective HP indicators.

The Grayscale Cursor Control circuits are shown on JPL drawing "Operator System Control Module, Sheet 1." They include the multiplexer for the computer and operator cursor control signals, the drivers for the signals to the Hughes 639 scan converter and the front panel mounted operator cursor mode control switches and position joystick.

The joystick is a Measurement Systems Model 522 digital joystick. The device's handle has a plane of freedom defined by vertical and horizontal orthogonal axes, the origin of which is the handle's rest position. The device has 4 pulse output terminals, one for each direction of the two axes. Pulse trains are generated when the handle is manually deflected from its center rest position. The trains generated and their pulse rates are proportional to the vector components of the handle deflection. The trains are used to increment or decrement the two cursor position registers, GSXCP and GSYCP. The rate at which the cursor is moved is therefore dependent upon the amount the operator deflects the cursor joystick. When the handle is released, it returns where it was positioned. The pulse trains are inhibited to the position registers whenever the computer has control of the cursor.

The Scan Converter Interface logic, depicted on JPL drawing "Operator System Control Module, Sheets 1 and 2," consists of high input impedance receivers for the Vertical Read Gate and Mode Switching Delay signals from the Hughes 639 scan converter to the GS Controller, differential receivers for the mode control, prime command and unblanking signals from the GS Controller to the scan converter and 3 D/A circuits for the horizontal and vertical deflections and intensity inputs to the scan converter.

The horizontal and vertical D/A deflection circuits each consists of 10 differential receivers for the digital deflection data from the GS Controller, a Teledyne/Philbrick Model 4004 12-bit DAC, a Teledyne/Philbrick Model 2203 $\pm$ 15 VDC power supply and an LM310D voltage follower. The 12-bit DAC is used to convert the 10-bit position data to obtain better linearity. The 91 ohm resistors on the DAC inputs are for noise suppression. The analog output is designed for ± 0.5 volts full scale deflection.

The intensity D/A circuit consists of 6 differential receivers for the digital intensity data from the GS Controller, a Teledyne/Philbrick Model 4020 DAC, a Teledyne/Philbrick Model 2211 ± 15 VDC power supply and an LM310D voltage follower. The analog output is designed for + 0.1 to + 0.5 volts adjustable full scale output.

The common pins of all 3 of the ± 15 VDC power supplies are tied together with heavy gauge wire to provide a stable analog ground reference.

Device Address Registers: The following pages show the bit definitions for the various device address registers.

BIT #	I/O (R/W)	BIT DESCRIPTION
15	R	Grayscale busy indicator (0/1 = busy/not busy)
14	W	Grayscale initialize (reads as A = zero)
13	*	
12	*	
11	*	
10	*	
9	*	
8	R/W	Cursor control source (0/1 = operator/computer)
7	R/W	Cursor state computer control (0/1 = constant/flashing)
6	R/W	Cursor element computer control (0/1 = crosshair/DOT)
5	R/W	Not used
4	R/W	No. of pixels/computer word (0/1 = 2/1 pixels per word)
3	R/W	Pixel replication control (0/1 = don't replicate/replicate)
2	R/W	Grayscale input operating 00 = No - op 01 = Selective erase/write
1	R/W	Mode control 10 = write 11 = selective erase
0	W	Full screen clear = 1 (reads as A zero)

*Reads as A 1

BIT #	I/O (R/W)	BIT DESCRIPTION
15	*	
14	*	
13	*	
12	*	
11	R/W	Not used
10	R/W	" "
9	R/W	" "
8	R/W	" "
7	R/W	Enable grayscale operation complete interrupt request
6	R/W	Not used
5	R/W	" "
4	R/W	" "
3	R/W	" "
2	R/W	" "
1	R/W	" "
0	R/W	" "

*Reads as A 1

BIT #	I/O (R/W)	BIT DESCRIPTION
15	*	
14	*	
13	*	
12	*	
11	R/W	Not used
10	R/W	" "
9	R/W	MSB
8	R/W	
7	R/W	
6	R/W	
5	R/W	Starting horizontal pixel position for an input operation (0 = left edge) (1023 = right edge)
4	R/W	
3		
2	R/W	
1	R/W	
0	R/W	LSB

*Reads as A 1

BIT #	I/O (R/W)	BIT DESCRIPTION
15	*	
14	*	
13	*	
12	*	
11	R/W	Not used
10	R/W	" "
9	R/W	MSB
8	R/W	
7	R/W	
6	R/W	
5	R/W	Line number of an input operation (0 = top edge, 1023 - bottom edge)
4	R/W	
3	R/W	
2	R/W	
1	R/W	
0	R/W	LSB

*Reads as A 1

BIT #	I/O (R/W)	BIT DESCRIPTION
15	*	
14	*	
13	*	
12	*	
11	R/W	Not used
10	R/W	" "
9	R/W	MSB
8	R/W	
7	R/W	
6	R/W	The 2's complement of the number of pixel bytes positions to be erased and/or written into.
5	R/W	
4	R/W	
3	R/W	
2	R/W	
1	R/W	
0	R/W	LSB

*Reads as A 1

BIT #	I/O (R/W)	BIT DESCRIPTION
15	*	
14	*	
13	*	
12	*	
11	R/W	Overflow negative
10	R/W	Overflow positive
9	R/W	MSB
8	R/W	
7	R/W	
6	R/W	
5	R/W	Horizontal co-ordinate of the cursor intersect (0 = lift edge 1023 = right edge)
4	R/W	
3	R/W	
2	R/W	
1	R/W	
0	R/W	LSB

*Reads as A 1

BIT #	I/O (R/W)	BIT DESCRIPTION
15	*	
14	*	
13	*	
12	*	
11	R/W	Overflow negative
10	R/W	Overflow positive
9	R/W	MSB
8	R/W	
7	R/W	
6	R/W	
5	R/W	Vertical co-ordinate of the cursor
4	R/W	intersect (0 = top edge, 1023 = bottom edge)
3	R/W	
2	R/W	
1	R/W	
0	R/W	LSB

*Reada sa A 1

BIT #	I/O (R/W)	BIT DESCRIPTION
15	R/W	Action indicator
14	R/W	Not used
13	R/W	" "
12	R/W	" "
11	R/W	" "
10	R/W	" "
9	R/W	Search indicator
8	R/W	Edit LO indicator
7	R/W	Edit 111 indicator
6	R/W	Scan indicator
5	R/W	Fob indicator
4	R/W	Check SP indicator
3	R/W	KTYP indicator
2	R/W	Check KT indicator
1	R/W	Mask indicator
0	R/W	Hardcopy indicator

BIT #	I/O (R/W)	BIT DESCRIPTION
15	W	MSB — Numeric display number code (see below)
14	W	
13	W	LSB
12	W	Not used
11	W	" "
10	W	" "
9	W	" "
8	W	MSB — Binary value of number to be displayed
7	W	
6	W	
5	W	
4	W	
3	W	
2	W	
1	W	
0	W	LSB

Display Code 15	14	13	Display Name
0	0	0	Spread Number
0	0	1	Scan Queue
0	1	0	Hardcopy Queue
0	1	1	Objective Magnificatic
1	0	0	Filter
1	0	1	Last Key
1	1	0	(Not Used)
1	1	1	(Not Used)

BIT #	I/O (R/W)	BIT DESCRIPTION
15	R/W	MSB — 2's complement of the number of pixel-words to be transferred via DMA.
14	↑	
13		
12		
11		
10		
9		
8		
7		
6		
5		
4		
3		
2		
1	↓	
0	R/W	LSB

BIT #	I/O (R/W)	BIT DESCRIPTION
15	R/W	MSB
14		
13		
12		
11		
10		
9		Address bits 15-0 of the grayscale pixel for a DMA
8		transfer.
7		
6		
5		
4		
3		
2		
1	R/W	LSB
0	R	Byte address bit (supplied by GS controller, always 0)

BIT #	I/O (R/W)	BIT DESCRIPTION
15	R	Error indicator
14	R/W	Non-existent memory error indicator
13	R	Attn (not used)
12	R/W	Maintenance diagnostic program bit
11	R	DSTATA (not used)
10	R	DSTATB (not used)
9	R	DSTATC (not used)
8	R/W	Cycle (1 = initiate DMA request when "Go" = 1)
7	R	Ready
6	R/W	IE DMA controller operation complete interrupt enable
5	R/W	XBA17 (entended DMA bus address bit)
4	R/W	XBA16 " " " " "
3	R/W	FNCT3 (not used)
2	R/W	FNCT2 (not used)
1	R/W	FNCT1 (not used)
0	W	GO (1 = initiate output to grayscale operation)

BIT #	I/O (R/W)	BIT DESCRIPTION
15	W	Not used
14	▲	Pixel byte B, MSB
13	│	" " "
12	│	" " "
11	│	" " "
10	│	" " "
9	│	" " ", LSB
8	│	Not used
7	│	" "
6	│	Pixel byte A, MSB
5	│	" " "
4	│	" " "
3	│	" " "
2	│	" " "
1	▼	" " ", LSB
0	W	Not used

Note: Pixel byte = 000000 = white
Pixel byte = 111111 = black

SECTION VII

HARDCOPY OUTPUT DEVICE

A. SYSTEM DESCRIPTION

Purpose and Function

The pictorial Hardcopy hardware consists of a special interface which controls the operation of a modified facsimile recorder through a DR11-B general purpose direct memory access interfact to the PDP-11 computer's Unibus.

Recorder

To produce a hardcopy output, electrosensitive paper is pulled through the recorder (Alden Electronics Model 9273/JPL) at a constant rate. An endless loop electrode perpendicular to the direction of paper drive provides a linear writing edge for the length of each scan line. Beneath this electrode is a helix wire mounted on a drum; the paper is fed between the two electrodes. This is shown schematically in figure 7-1. The intersection between the helix wire and endless loop electrode forms a writing point which becomes a "flying spot" when the drum is rotating. Thus a single picture line is recorded for each drum revolution. The density of the recorded spot is determined by the current passing through the paper at the writing point and is controlled by 4 pixel value lines to produce 16 different gray levels (called tone shades by Alden). The pixels within a line are synchronized by an optical encoder which outputs 1024 clock pulses per line. The start of each scan line is indicated by a single pulse.

Hardcopy Interface

The hardcopy interface (HCI) controls the recorder paper drive and synchronizes the pixel value lines with the pixel clock and start line signals from the computer via direct memory access (DMA) and has error detecting logic. A test mode to verify recorder operation is also available.

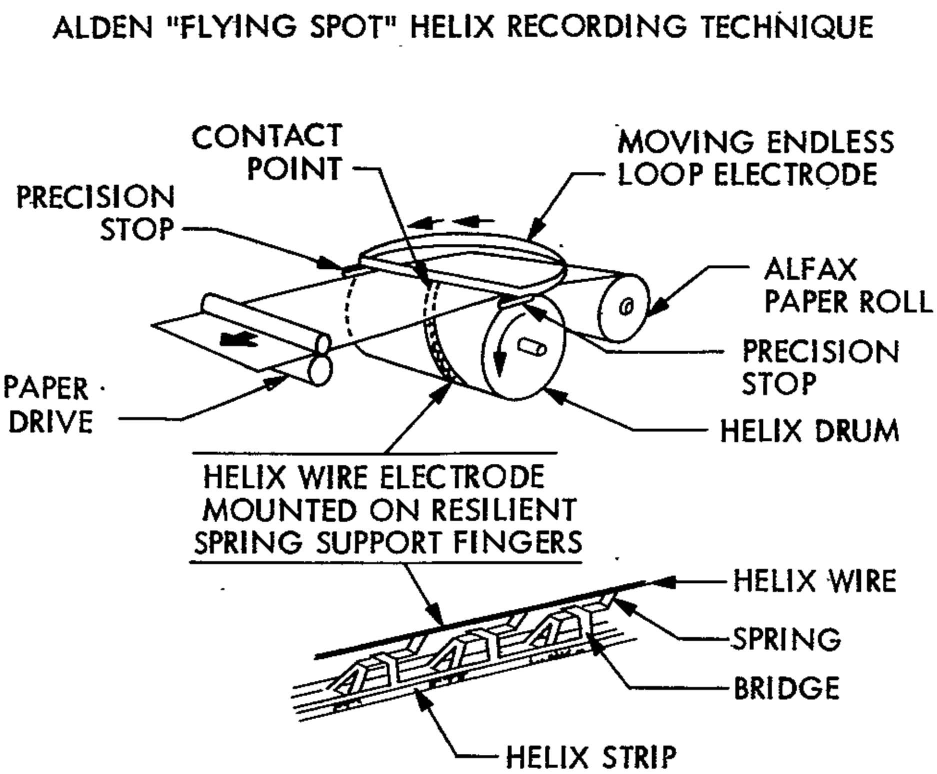


Fig. 7-1 Alden "Flying Spot" Helix Recording Technique

Computer

The computer obtains data from the disc and sets up the DR11-B for DMA transfer of each line, formatting the data as necessary. This is a low duty cycle operation; however, the hardcopy recorder must receive pixel values at a constant rate during output. The computer must also check the status of the HCI and provide the signals necessary to control the starting and stopping of the recorder and to set up the mode desired for the transfer of data.

General Performance Specifications

The modified facsimile recorder produces pictorial hardcopy output from disc data sets. The output typically consists of about 1000 lines each with above 1000 pixels. Each pixel may be recorded at one of 16 gray levels. Pixel spacing is 96 per inch resulting in an image approximately 10 inches square on the 11 inch wide recording paper.

Additional specifications are listed below:

1) Pixels per line - 1020 maximum

2) Lines per frame - limited by 120-foot paper roll length

3) Pixel spacing - 96 per inch nominal

4) Line spacing - 96 per inch nominal

5) Gray levels - 16

6) Recording rate - 8 lines per second

Power requirements are:

1. Recorder - 115 VAC, single phase, 60 Hz (250 watts)

2. Interface - + 5 VDC, 1.5 Amps

B. INTERFACING REQUIREMENTS

Hardware Requirements

The HCI is connected to the PDP-11 Unibus by means of a DEC DR11-B general purpose DMA interface and is mounted in a 5¼ inch rack space physically separate from the DR11-B. Connection is made via cables. All data and control lines are at TTL levels and within the HCI SN7404 drivers/receivers are employed. The same TTL levels and driver/receiver types are also used for the data and control lines between the recorder and the HCI. The recorder is a table top unit consisting of the recorder head assembly and the electronics (control) unit. It is physically separate from the HCI.

Software Requirements

DR11-B Register Usage

The section explains use of the four DR11-B registers in the hardcopy interface software. More details may be found in DR11-B Manual, Digital Equipment Corp. (DEC-11-HDRC-D).

1) Word Count Register (DRWC) - Loaded with 2's complement of the number of transfers to be made in a line. Increments up toward zero with each bus cycle.
2) Bus Address Register (DRBA) - Specifies direct bus address. Increments by +2 after each bus cycle advancing to the next sequential word location.
3) Status and Command Register (DRST) - Used to give commands to the hardcopy interface and to provide status indicators of the DR11-B control and the hardcopy interface. Function and Status bits only will be discussed here (the DR11-B Manual provides detailed descriptions of the remaining bits).

a) Function Bits (FNCT-1, -2, -3) - These three bits control the operation of the recorder and data transfer modes available in the HCI.

FNCT 1 = FRAME = Starts output on logic 0 to 1 transition. Stops output after logic 1 to 0 transition.

FNCT 2 = LXPND = Line Expand mode at logic 1. Hardcopy pixels repeat giving twice the number of input pixels on the hardcopy. This effectively expands each line horizontally by a factor of two. The computer must repeat lines to expand vertically.

FNCT 3 = PDATA = At logic 1 four 4-bit hardcopy pixels per 16-bit word. At logic 0 two 4-bit hardcopy pixels per 16-bit word.

b) Status Bits (DSTAT A, B, C) - These three bits show recorder status or error type as indicated below.

With ATTN=0, Recorder Status is shown.

DSTAT A = HCRDY - Recorder and interface ready to start output. (Goes to logic 0 with RUN).

DSTAT B = RUN - Paper moving through recorder.

DSTAT C = LOP - Paper supply low in recorder. (Not used at present, strapped to logic 1).

With ATTN = 1, Error types indicated. (See Section II). [Note: Present software does not utilize the error detesting feature. Therefore ATTN is strapped to logic zero. Timeout errors are indicated on the test panel, however,]

DSTAT A = CRTO = Cycle Request timeout.

DSTAT B = PCTO - Pixel Clock timeout.

DSTAT C = SLTO - Start Line timeout.

4) Data Buffer (DRDB)

MSB	15 12	11 8	7 4	3 0	LSB

	Hardcopy Pixel with LXPND=0	Hardcopy Pixel with LXPND=1	DRDB bits
PDATA=1	1 2 3 4	1,2 3,4 5,6 7,8	3-0 7-4 11-8 15-12
PDATA=0	1 2	1,2 3,4	6-3 14-11

The above table shows how data is transferred from the DRDB to the hardcopy. Hardcopy pixel sequences for each mode repeat for each complete line.

5) Initialization

The HCI is initialized by the Unibus INIT signal, the Master Reset pushbutton, or powering up the HCI. Initialization stops any frame in progress and sets up all circuitry for transfer of data and recorder control.

Status Checks

Status checks should be performed before the start of output and at the start or end of each line. This is accomplished by reading the three DSTAT bits in the DRST register. Software Requirements paragraph gives an explanation of the status bits.

Recorder Start/Stop

The recorder starts with the logic 0 to logic 1 transition of the FNCT 1 bit (FRAME) in the DRST if HCRDY (DSTAT A) is true. While the helix drum in the recorder is coming up to speed, 16 blank lines are recorded before the first picture line. The FNCT 2 (LXPND) and FNCT 3 (PDATA) bits should be set as desired along with the FRAME bit. After the last picture line has been recorded the FRAME bit must be reset to initiate the recorder stop sequence. Sixteen blank lines are recorded; then the recorder stops and the hardcopy output is available.

Picture Line Transfer

Each line of the hardcopy output is transferred via direct memory access. The DRWC and DRBA registers must be properly set up before the start of line pulse (STL) is received from the recorder. STL generates the first cycle request. The HCI thereafter generates cycle requests based on the hardcopy pixel sequences needed for the data transfer mode selected by PDATA and LXPND. A maximum of about 1020 hardcopy pixels per line may be recorded. The exact value depends on the time required to service the interrupt which occurs at the end of data transfer (word count overflow) for the line and to prepare the DR11-B for transferring the next line. There is a minimum of about 250 microseconds between cycle requests (125 microseconds between hardcopy pixels). STL occurs every 125 milliseconds (8 lines per second).

Interrupts

Interrupts can occur for two reasons:

A. Word count overflow (end of picture line).

B. Time out errors.

Interrupt A is sent by the DR11-B when READY is set by word count overflow. Interrupt B may be sent by the HCI via ATTN, however it is not now used.

Timeout Errors

As now implemented, errors are indicated on the test panel, but do not cause an ATTN interrupt.

a) CRTO - Cycle Request Timeout - Too long between cycle requests during the transfer of a picture line (> 600 microseconds).

b) PCTO - Pixel clock timeout - Recorder pixel clock rate is below the minimum acceptable (7.4 KHz) during a frame.

c) SLTO - Start of line timeout - Recorder line rate is below 7.2 lines per second during a frame.

C. THEORY OF OPERATION

Elementary Theory of Operation

Operation of the HCI can best be described with the aid of the block diagram shown in Fig. 7-2.

Data Transfer

Data on the 16 data output lines from the DR11-B are stored and multiplexed to select the appropriate 4 bit pixel value at the correct time. The multiplexing is controlled by the data transfer logic which is set to the proper transfer mode by the DR11-B. The pixel value output to the recorder is taken from either the multiplexed data in OPERATE mode or the test gray level in TEST mode.

Recorder Control

The control and drive logic serves to start and stop the recorder, to time the transfer of data as required by the recorder in accordance with the data transfer mode, and to generate status for the DR11-B. The error logic detects each of the three timeout errors and interrupts the computer upon error. The DSTAT gate puts recorder status on the three DSTAT lines to the DR11-B in normal operation; the lines will contain error type whenever an error-generated interrupt occurs (ATTN). Presently, however, ATTN is not used.

Detailed Theory of Operation

To follow the detailed theory of operation more clearly, the reader is referred to the following for reference:

a) HCI Block Diagram - Fig. 7-2.

b) DEC DR11-B manual

c) HCI Logic Diagrams (3 sheets)

C-3

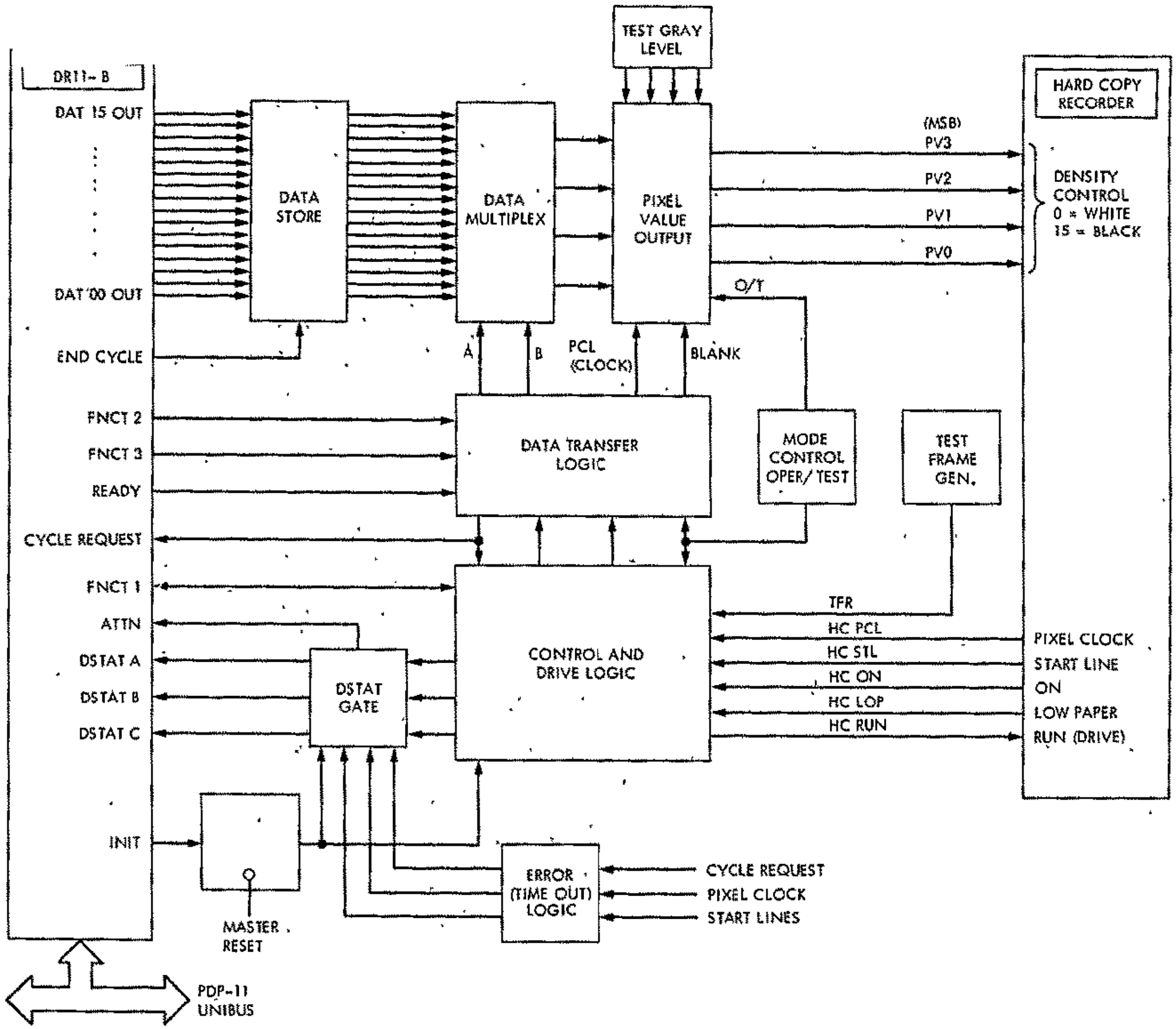


Figure 7-2 Hardcopy Interface Block Diagram

DR11-B: The computer handshaking operations of the DR11-B are explained in detail in the DEC DR11-B Manual. However, the factory installed wiring for Device Address, Vector Address, and Priority Interrupt Level have been changed to the following:

Register Addresses (octal): 772430-772437

Vector Address (octal): 440

Priority Interrupt Level: BR7

Data Handling Logic (Sheet 1)

This describes the Data Store, Data Multiplex, Pixel Value Output and Test Gray Level blocks in the HCI Block Diagram, Fig. 7-2.

The 16 data output lines from the DR11-B are buffered and the data stored in a flip-flop register (type SN7475 IC's). The register is clocked by END CYCLE from the DR11-B. Data multiplexing is accomplished with two type SN74153 IC's. The truth table for these IC's is shown below:

BSelect	ASelect	Selected Output	Strobe
L	L	CO	L
L	H	C1	L
H	L	C2	L
H	H	C3	L
H or L	H or L	L	H

Note: L = low level, logic 0; H = high level, logic 1

The CO and C2 inputs to the Data Multiplexer are shifted when PDATA = 0 in order to obtain the DRDB bits. The table below summarizes the data multiplexing process giving the four-bit output pixel sequences for the various data transfer modes.

	Hardcopy Pixel LXPND=0	Hardcopy Pixel LXPND=1	Data Multiplexer Select Lines B	Data Multiplexer Select Lines A	Data Multiplexer Output Selected	DRDB Bits for Pixel Value
PDATA=0	1	1,2	H	L	C2	6-3
	2	3,4	L	L	C0	14-11
PDATA=1	1	1,2	H	H	C3	3-0
	2	3,4	H	L	C2	7-4
	3	5,6	L	H	C1	11-8
	4	7,8	L	L	C0	15-12

The four-bit output from the data multiplexer is held in the Pixel Value register which is clocked at the leading edge of the pixel clock from the recorder. The pixel value lines to the recorder contain the test gray level in TEST mode and the Pixel Value register output in OPERATE. All pixel value lines are held at logic zero during the start/stop blank lines and during inactive picture line times.

Data Transfer Control and Recorder Drive Logic (Sheet 2)

This section describes the recorder start/stop sequence, control of the data multiplexer, and DMA cycle requests.

The recorder start/stop sequence allows a number of blank lines to be recorded before the start of the active frame to ensure that the paper drive within the recorder is up to speed before data is recorded. A similar process records blank lines at the end of each frame before the recorder is stopped. The RUN signal to control the recorder paper drive is generated by the RUN flip flop. RUN is set by the frame start (FRST) pulse which occurs on the leading edge (0 to 1 transition) of the FRAME signal. FRAME is the FNCT 1 bit from the DR11-B in OPERATE mode or TRF (test frame) in TEST mode. RUN can be set only if the recorder is ON and in DATA mode, the low paper signal (presently not used) is a high level, and RUN is not set already. RUN is reset when M blank lines have been recorded after FRAME goes to zero.

The SPDLY (Stop Delay) flip-flop is set to accomplish this. M is presently 16, but may be changed by wiring the jumper plug as desired. The STDLY (Start Delay) flip-flop is set after N blank lines at the start of FRAME. N is now 16 but can be changed in the same manner as M above. STDLY allows transfer of data to begin after the N blank lines have been recorded. Data transfer is controlled by four flip-flops (A, B, C, and LINE) and start line (STL) and Pixel Clock (PCL) pulses from the recorder. Figure 7-3 shows the timing for the LINE flip-flop and the associated control circuitry. Figure 7-4 gives timing for the transfer of data within each line including DMA cycle requests.

Status, Error, and Miscellaneous Circuits (Sheet 3)

Status is put on the three DSTAT lines in OPERATE mode. ERST latches the indication of error condition and MRST (master reset) must be used to clear the error. Master Reset is generated by the + 5 volts coming up, depressing the master reset button on the control panel, or via INIT (the Unibus Initialize signal). The OPERATE/TEST mode is determined by the switch setting and utilizes cross-coupled NAND gates to eliminate switch bounce as shown on the schematic. The TEST FRAME START/STOP switch generates a pulse when depressed and then released. This pulse is AND'ed with TEST mode and is used to toggle a J-K flip-flop TFR (test frame).

DR11-B Registers

This section explains use of the four DR11-B registers in operating the hardcopy interface.

1) Word Count Register (DRWC) - loaded with 2's complement of the number of transfers to be made in a line. Increments up toward zero with each bus cycle.

2) Bus Address Register (DRBA) - specified direct bus address. Increments by + 2 after each bus cycle advancing to the next sequential word location.

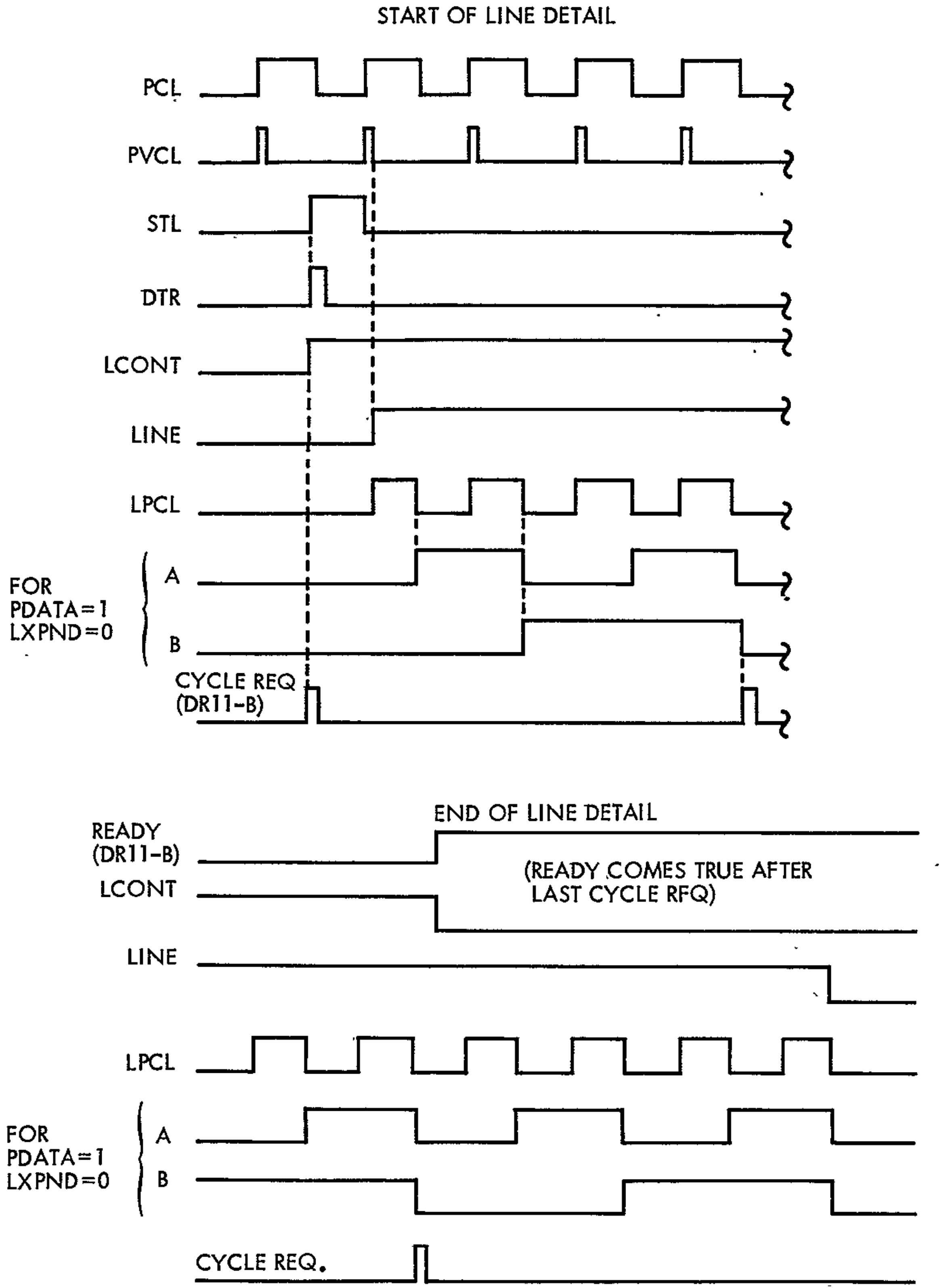


Figure 7-3 HCI Line Timing

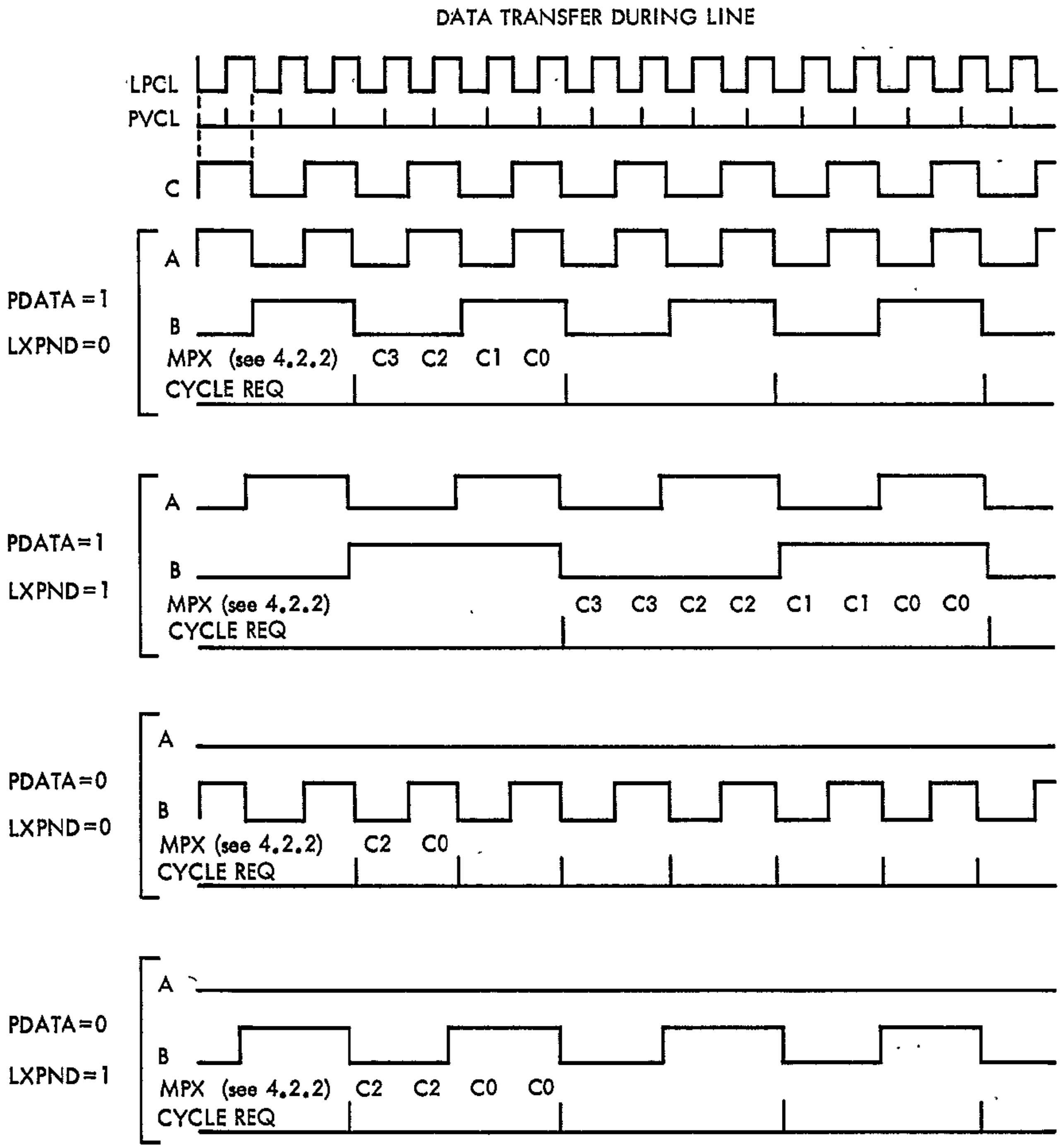


Figure 7-4 HCI Pixel Timing

3) Status and Command Register (DRST) - used to give commands to the hardcopy interface and to provide status indicators of the DR11-B control and the hardcopy interface. Function and Status bits only will be discussed here (the DR11-B Manual (Vol. I Ref. 8) provides detailed descriptions of the remaining bits).

a) FNCT 1 = FRAME = Starts output on logic 0 to 1 transition. Stops output on logic 1 to 0 transition.

b) FNCT 2 = LXPND = Line Expand mode at logic 1. Hardcopy pixels repeat giving twice the number of input pixels to the hardcopy. This effectively expands each line by a factor of two. The computer must repeat lines to expand vertically.

c) FNCT 3 = PDATA = At logic 1 four 4-bit pixels per 16-bit word. At logic 0 two 4-bit pixels per 16-bit word.

d) DSTAT A,B,C (ATTN=0) - Recorder Status as shown below.

A = HCRDY - recorder and interface ready for output.

B = RUN - paper moving through recorder.

C = LOP - paper supply low in recorder.

e) DSTAT A,B,C (ATTN=1) = Error type.

A = CRTO - Cycle Request timeout.

B = PCTO - Pixel Clock timeout.

C = SLTO - Start Line timeout.

4) Data Buffer (DRDB).

MSB	15	12	11	8	7	4	3	0	LSB

The table below shows how data is transferred from the DRDB to the hardcopy. Hardcopy pixel sequences for each mode repeat for each complete line.

	Hardcopy Pixel with LXPND=0	Hardcopy Pixel with LXPND=1	DRDB Bits
PDATA=1	1	1,2	3-0
	2	3,4	7-4
	3	5,6	11-8
	4	7,8	15-12
PDATA=0	1	1,2	6-3
	2	3,4	14-11

Functional Description

The following is a functional description of the operations performed by the hardcopy interface, recorder, and computer to produce and output picture. A summary is given in Fig. 7-5.

Note: Abbreviations not previously used:

HC = Hardcopy

I/F = Interface

N = No

PCL = Pixel clock

STL = Start Line

Y = Yes

1. Check status for $\overline{\mathrm{ATTN}}\cdot\mathrm{HCRDY}$

   Y - Proceed

   N - Print error and and (13)

1. Returns status bits

2. Get 1st line and format if necessary.

2. No action.

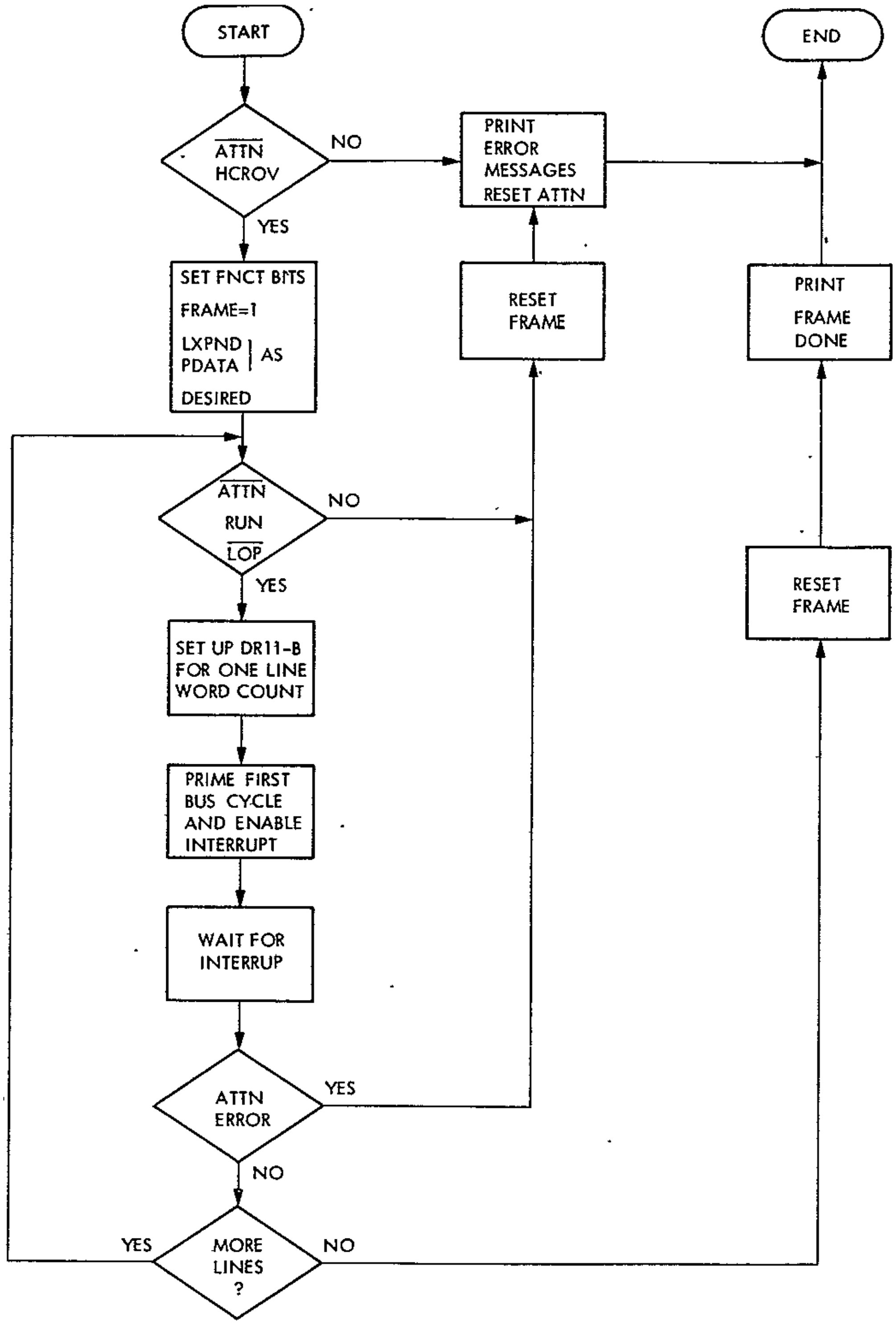


Figure 7-5 Hardcopy Basic Flow Diagram

3. Set FNCT bits - (1) FRAME = 1 (2) LXPND (3) PDATA as desired	3. Recorder starts. (0→1 FRAME transition) 16 x 125 ms 2 sec start up blank lines
4. Check status for $\overline{ATTN}$ · $\overline{LOP}$ · DRIVE Y - Proceed N - Reset FRAME. Print error and end (13)	4. Returns status bits.
5. Set up DR11-B for line transfer.	5. No action.
6. Prime the 1st bus cycle and enable interrupt.	6. 1st word loaded into I/F.
7. Get next line and format if necessar.	7. STL (after start-up) begins DMA. HC pixel values are read from DRDB word as determined by PDATA and LXPND.
8. Wait for interrupt.	8. Cycle requests to DR11-B for next DRDB word when required 250 μs (minimum between cycle request), 125 msec between STL.
9. Interrupt occurs.	9. Sends interrupt for a. WC overflow (end of line) [This blanks rest of H.C. line.] b. Time out error 1) PCL 2) STL 3) Cycle request Note: A is sent by DR11-B when READY is set by WC overflow. B is sent by I/F via ATTN.
10. Check status for ATTN ERROR Y - Reset FRAME, print error and end N - Continue	10. Returns status.

11. Check for more lines. Y - Go to 4 N - Continue	11. No action
12. Reset FRAME.	12. Recorder stop sequence is initiated. Blank lines recorded (1-16). Recorder stops.
13. End.	13. Hardcopy output available.

INIT (to Reset ATTN)

Errors

1. Status check before start of output.

   Print: "Recorder Not Ready"

2. Status check before each line.

Print:	"Error:	if ATTN = 1
	"Recorder Not Running"	if ATTN = 0, RUN = 0
	"Low Paper Supply"	if ATTN = 0, LOP = 1

3. ATTN interrupt during output for errors.

   a. Error types.

      1) PCL timeout - hardcopy pixel clock too slow

      2) STL timeout - hardcopy start lines too slow

      3) Cycle request timeout - too long between cycle requests after start line from hardcopy recorder.

   b. Indicator of error type: ATTN = 1

      DSTAT A - Cycle request timeout

      B - Pixel clock timeout

      C - Start line timeout

   c. Print error type(s) indicated by DSTAT bits

SECTION VIII
SPECIMEN PREPARATION SYSTEM

This section contains drawings of the components which were designed and constructed at City of Hope prior to and during the period of the contract.

Medium Dispensing Unit

Figure 8-1 shows a side view of the medium dispensing unit, support stand and base with a culture tray inside. The Polydrop manifold is a purchased item which was adapted for use in this component. The top view shown in Fig. 8-2 gives the dimensions of the unit and depicts the guides which center the tray under the manifold.

Fluid Dispenser

Figure 8-3 shows a side view of the fluid dispenser which is mounted on the plate of a shaker. Figure 8-4 shows an end view of the dispenser with details of the supports for the needle manifold. Figure 8-5 shows a side view of the fluid dispenser with dimensions of inter-needle spacing.

Aspirator

Figure 8-6 illustrates the aspirator with the manifold and spring suspension.

Slide Dispenser, Cell Dispenser and Cell Spreader

The details of the assembly for making slides is shown in a side view in Fig. 8-7. The components are depicted in their working positions with dimensions. In Fig. 8-8, a top view of this assembly is shown and the dimensions of slide chutes are shown in Fig. 8-9.

The positions of each component of the console are shown in Fig. 8-10.

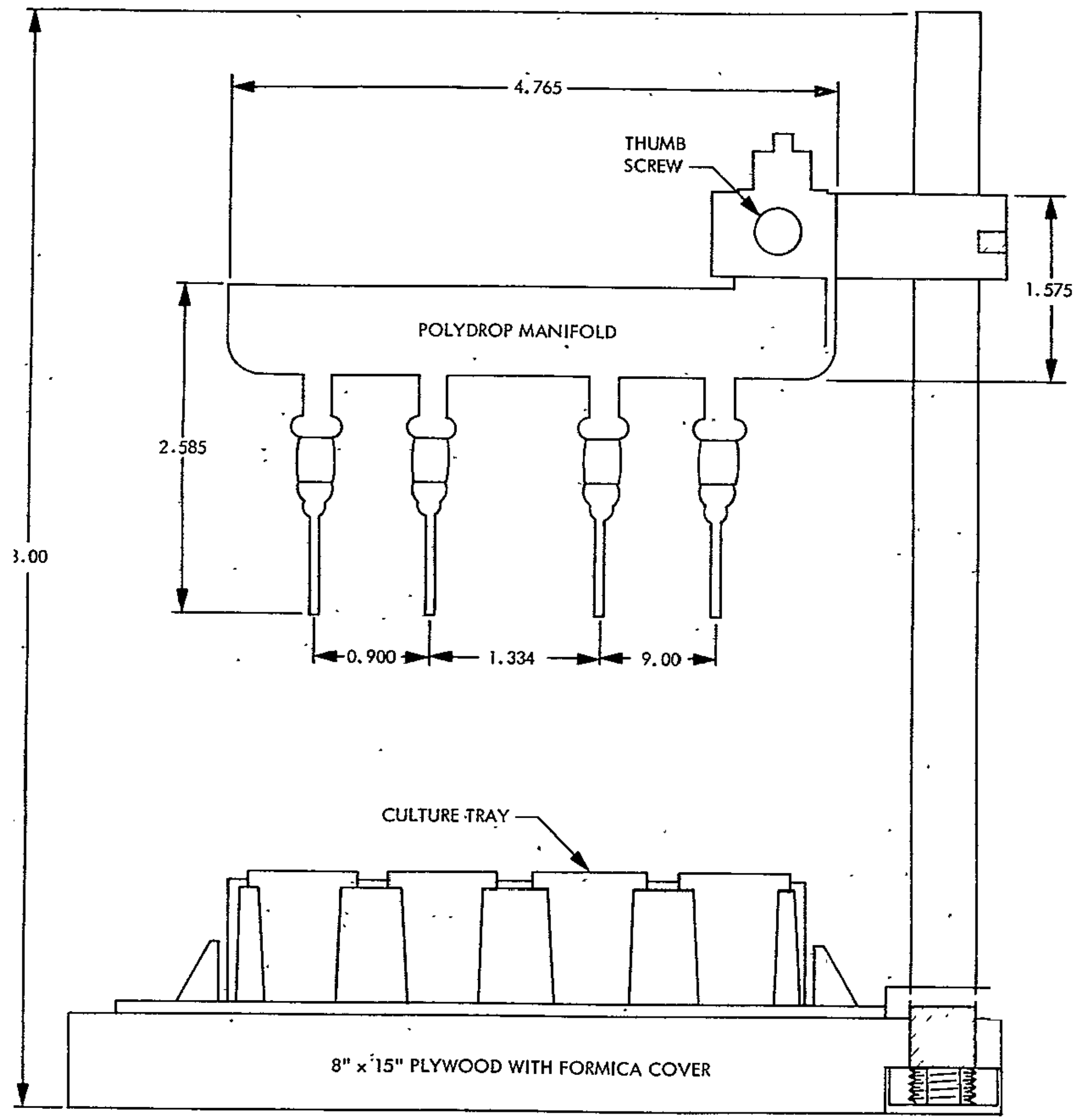


Figure 8-1 Medium Dispenser Side View

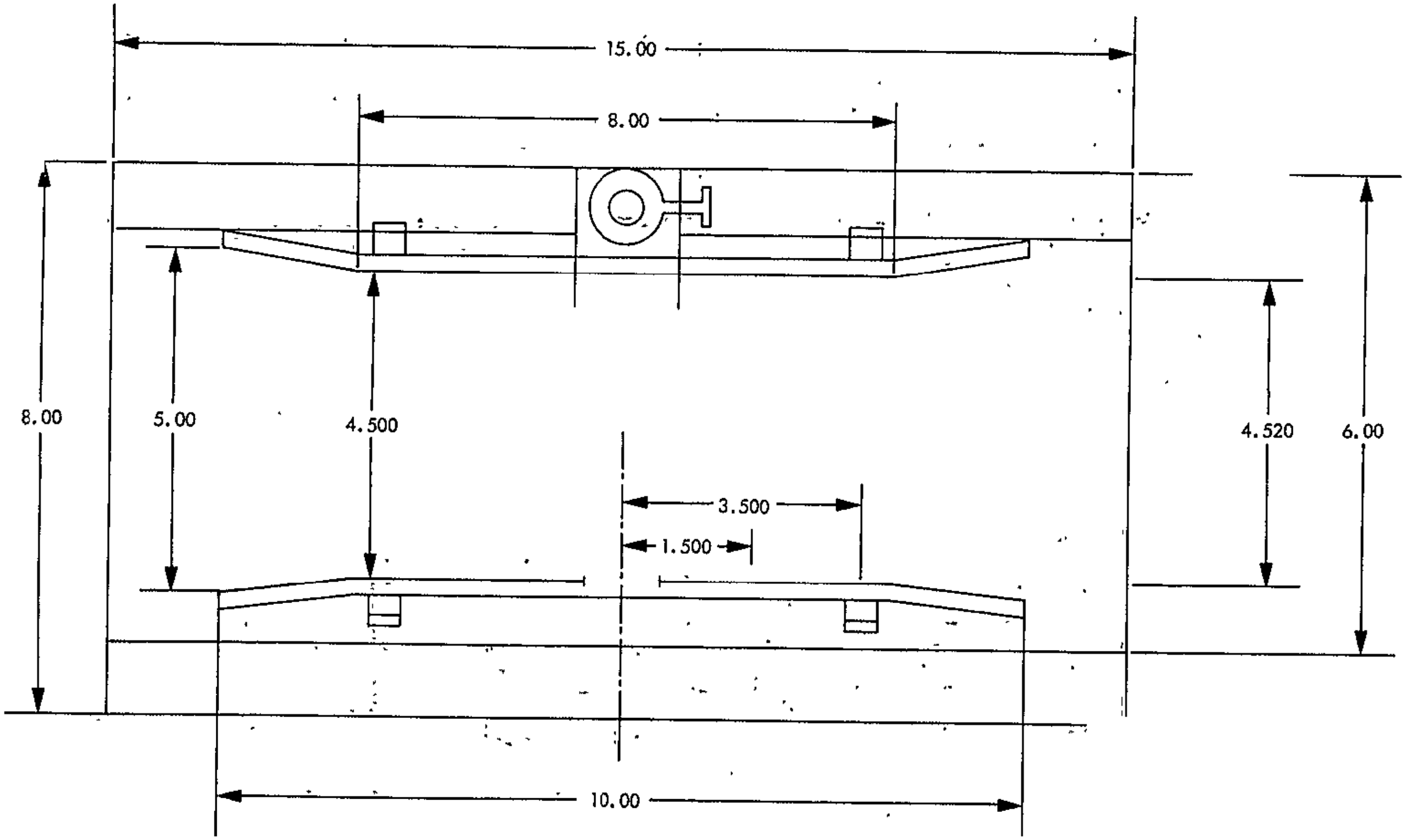


Figure 8-2 Base of Medium Dispenser Top View

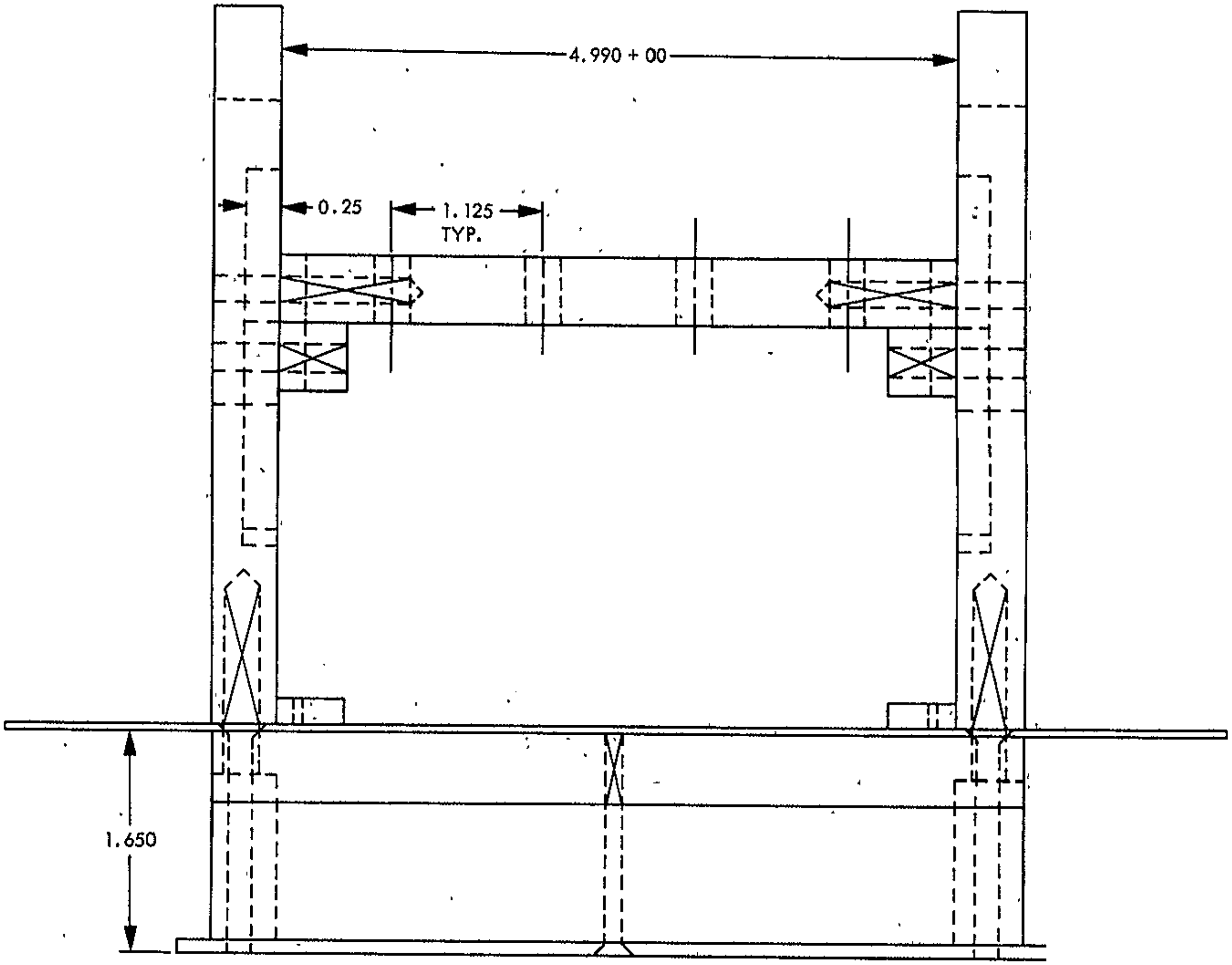


Figure 8-3 Fluid Dispenser Side View

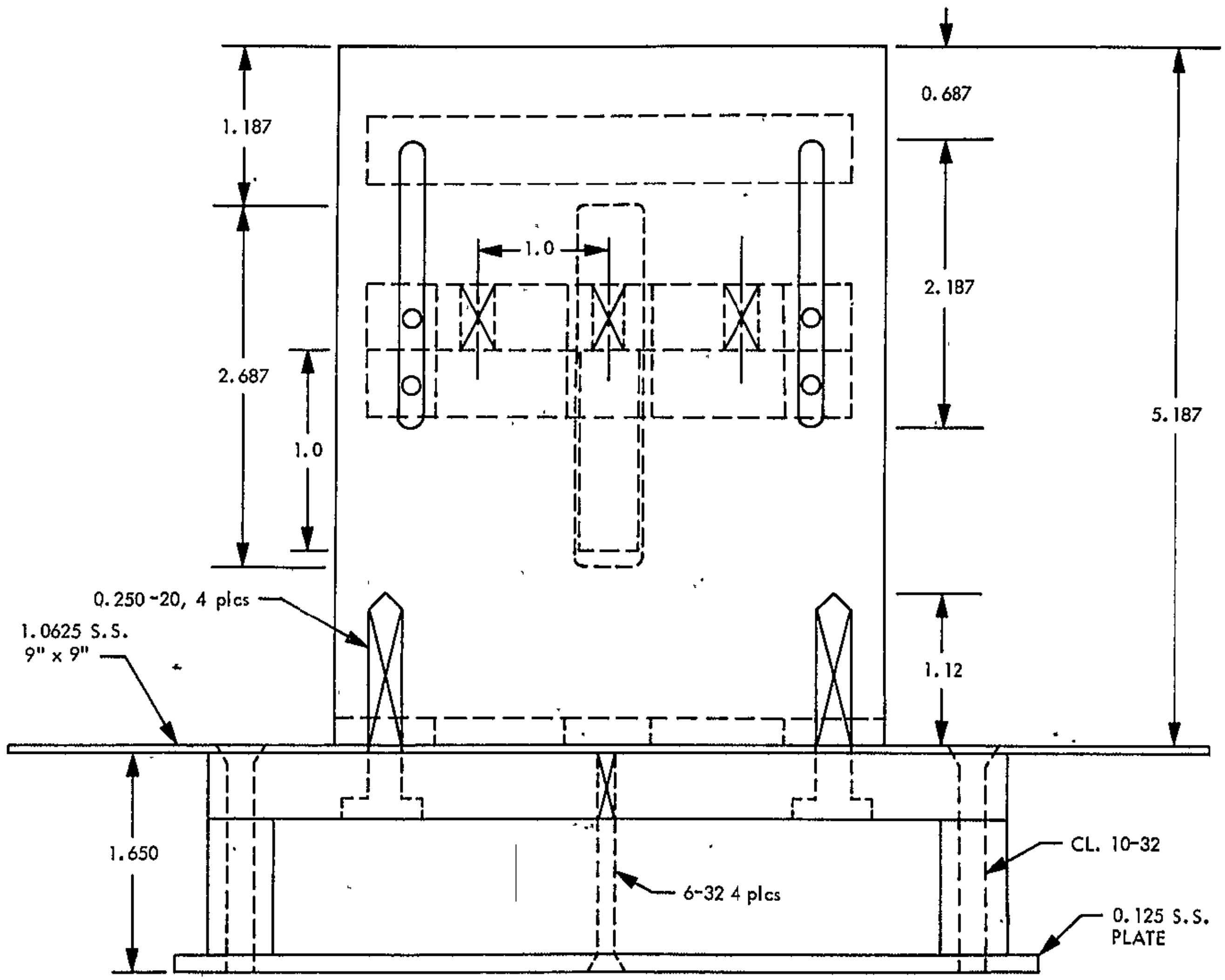


Figure 8-4 Fluid Dispenser End View

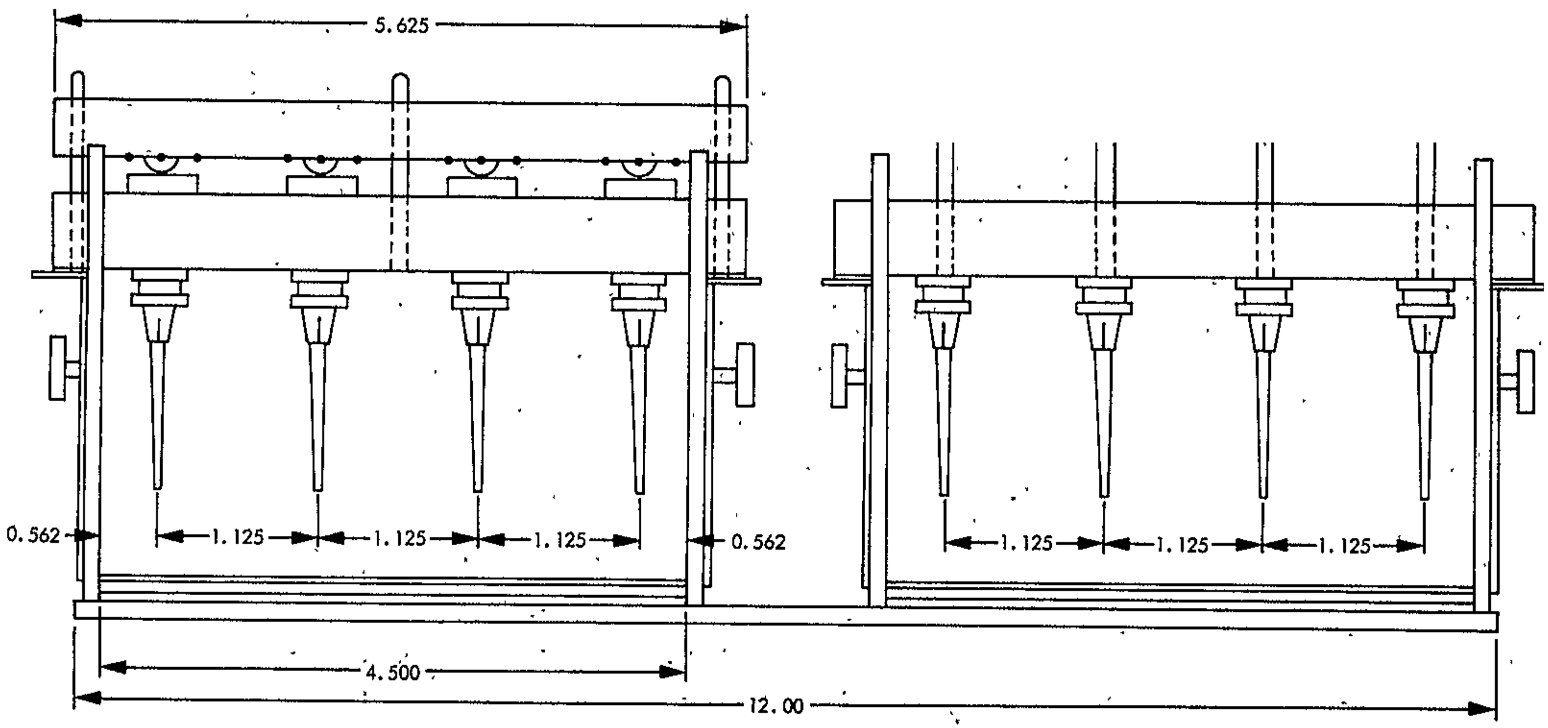


Figure 8-5 Needle Positions of Fluid Dispenser Side View

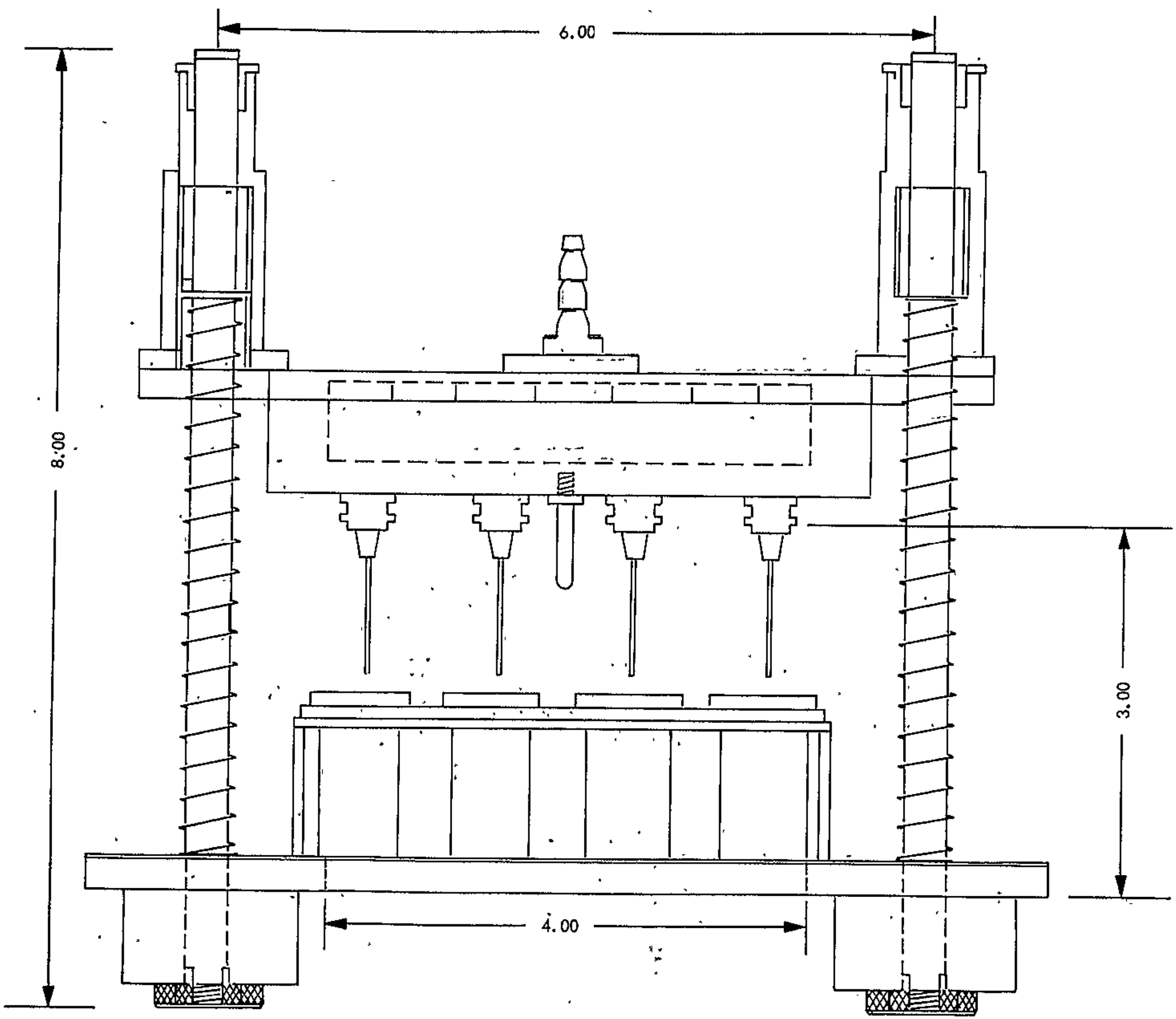


Figure 8-6 Aspirator

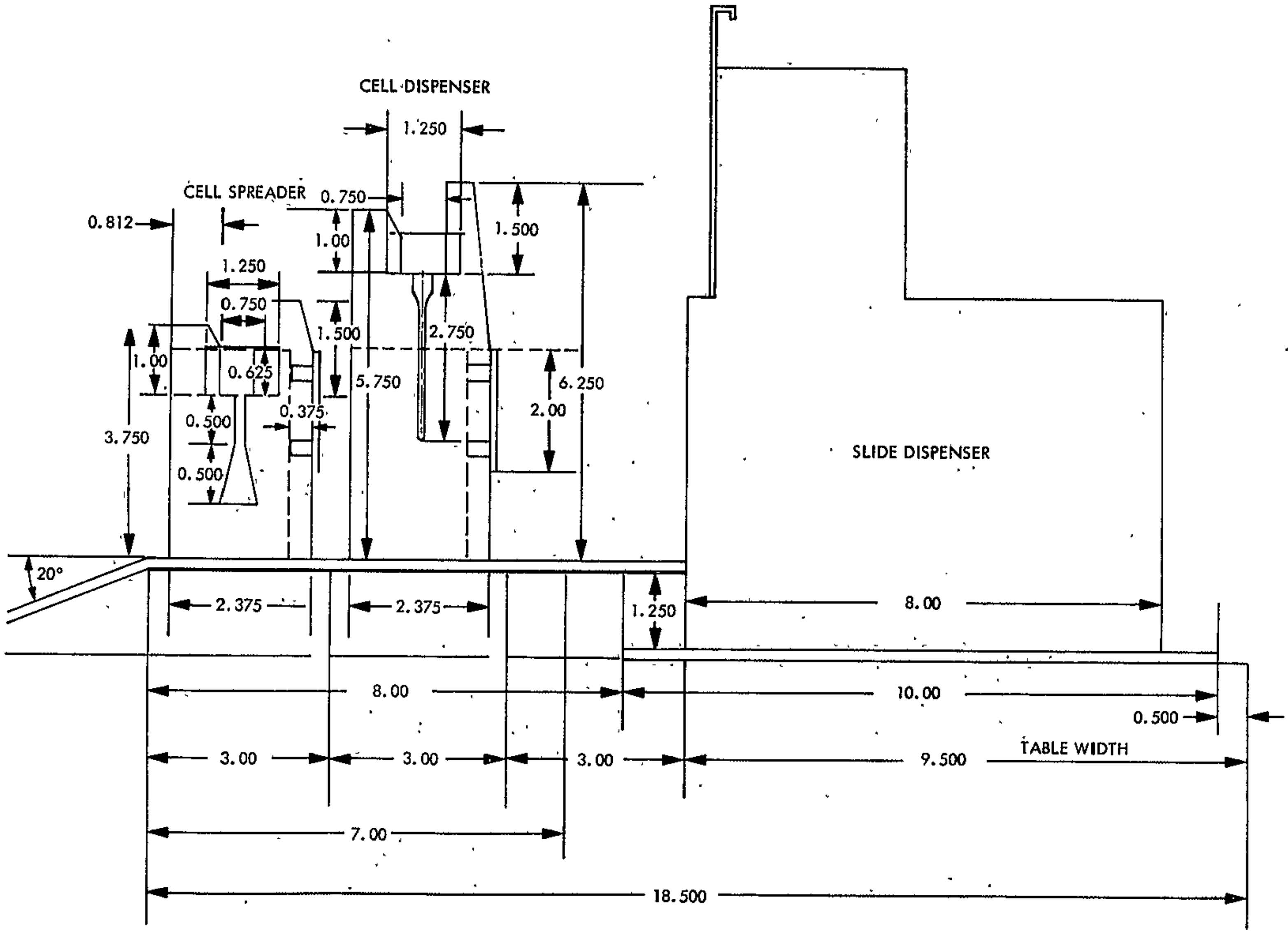


Figure 8-7 Slide Dispenser, Cell Dispenser and Cell Spreader. Side View

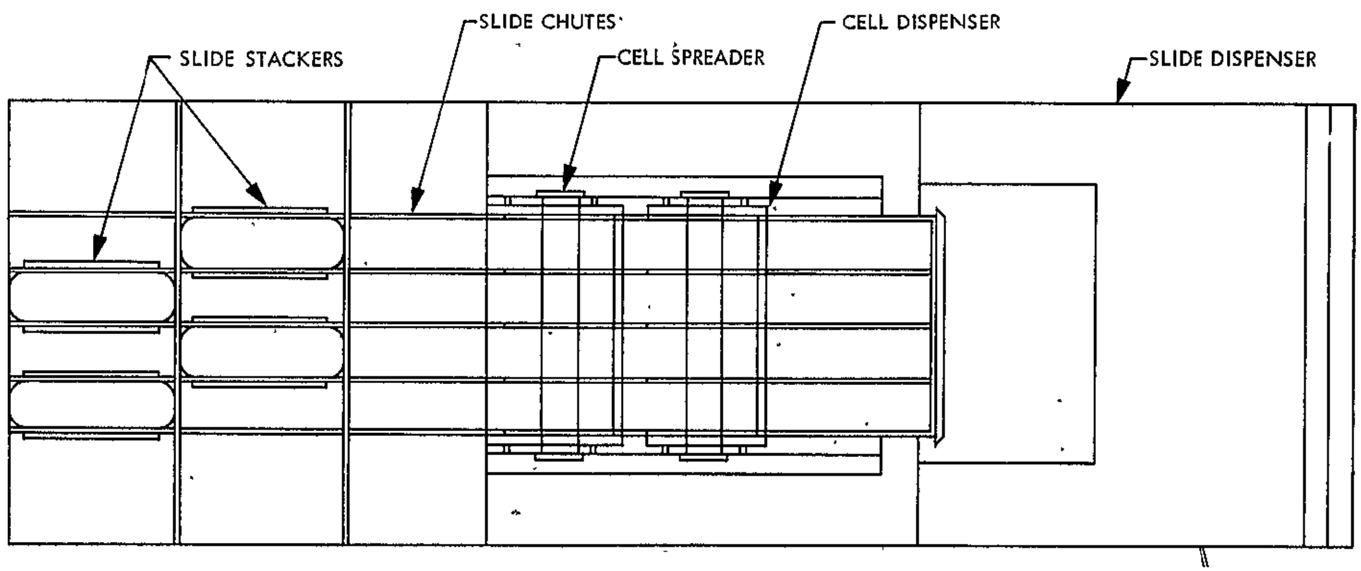


Figure 8-8 Slide Dispenser Top View

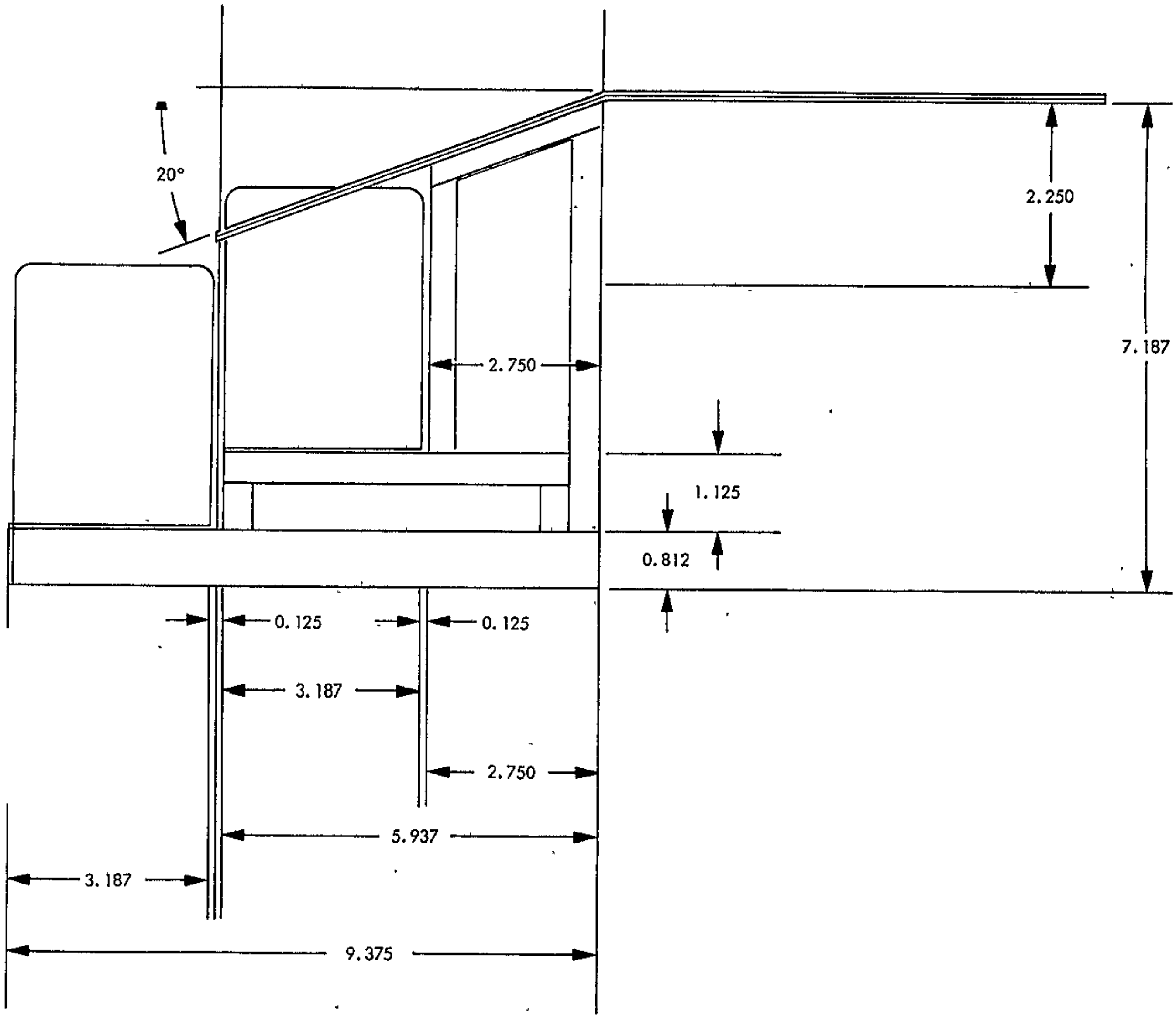


Figure 8-9 Slide Dispenser Chutes Side View

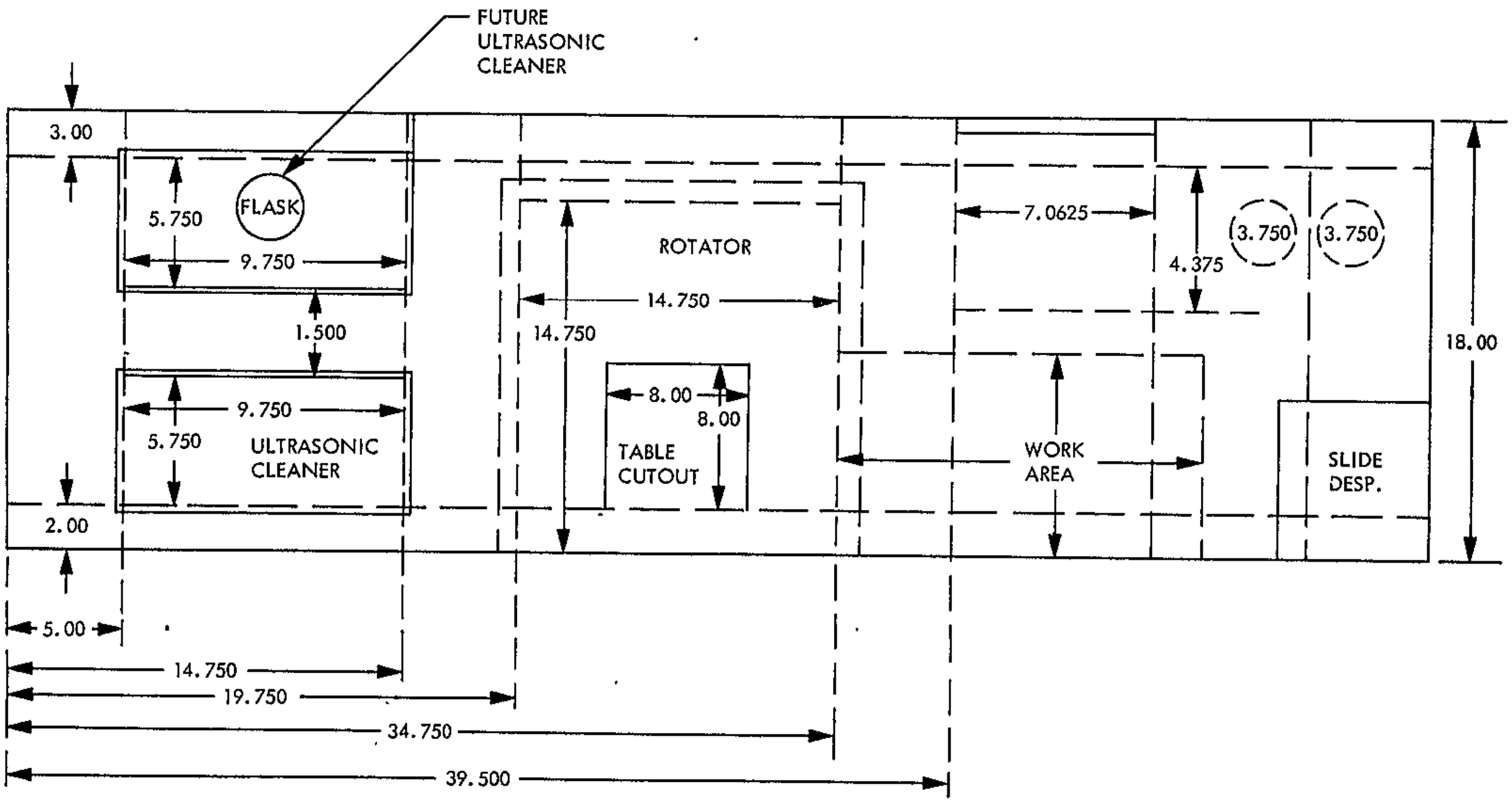


Figure 8-10 Console Component Positions

SECTION IX

MAINTENANCE

A. MOTOR CONTROL INTERFACE

Periodic Maintenance and Calibration

There is no requirement for periodic maintenance. The only calibration required is that of the two MCI clocks. They should be adjusted to the following rates:

XYMCLK - 400 PPS, ± 10%

FMCLK - 400 PPS, ± 10%

B. SPREAD DETECTOR/AUTOFOCUS UNIT

Calibration

The complete calibration procedure described in this section need be performed only during initial set up of the system or after major changes or modifications, such as active component replacement, changes in video and/or sync level, or use of a different optical magnification. Additionally, the controls which set up the spread acceptance criteria may need adjustment to optimize performance.

Sync

Composite Sync from the TV system is input through an NE529 analog comparator whose output signal (CS) triggers a series of one-shots (SN74121) to produce active line (AL), strobe (STRB), and reset (RST) signals. These signals synchronize and control the generation of spread presence and focus parameters. Nominal times for the five one-shots are given on the schematic; a timing diagram appears in Fig. 9-1. The order of adjustment should be from left to right across the top row on the schematic. The input of gate 2A2 (pin 12) may have to be temporarily grounded to initially set up the first two one-shots.

Spread Detection

Calibration for the spread detection function involves three areas. They are listed below along with the procedure to be employed for each.

Threshold - In addition to the front panel control, there are two pots which set up the amount of low-pass filtered video applied to the video comparator reference input. The 2K control determines time constant, the 25K control sets the amount of video. Start with the 25K control at the maximum counter-clockwise position, and the 2K control at the mid point of its range. Change the controls from this setting only if unsatisfactory thresholding is obtained. The A and B inputs of the NE 529 video comparator (GCOMP) should be observed simultaneously if the two controls need adjusting.

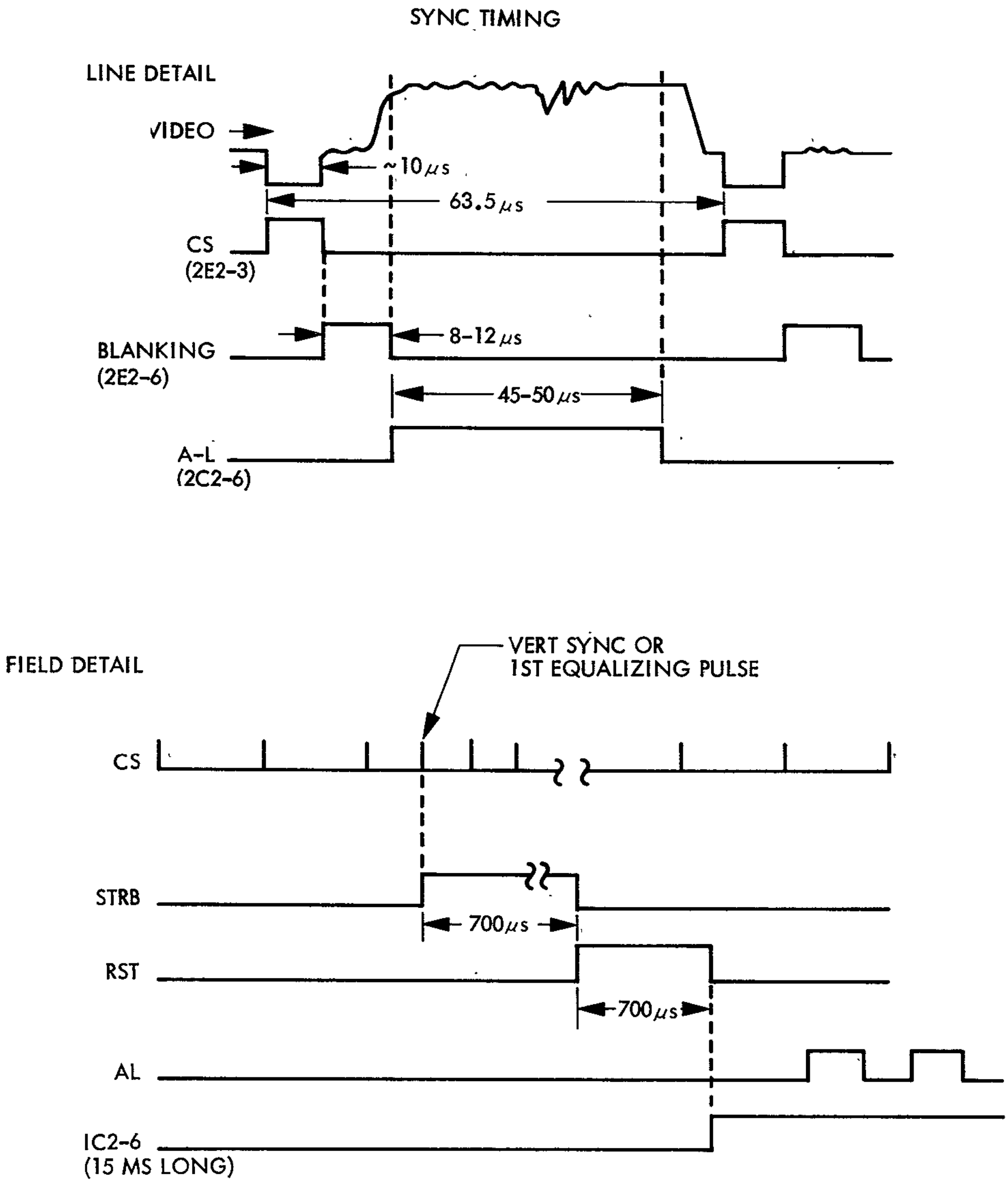


Figure 9-1 Sync Timing

Time Window Limits - Four controls set up the time window limits for counting valid threshold crossings. TMAX is the maximum time, TMIN is the minimum time, TEND is the count pulse (gated to the counter clock input during the active line time). SAG (spread area gate) may be wired in to control the minimum chromosome spacing necessary for the AREA integrator to function; it is not presently used, however. The nominal times are given on the schematic. However, TMAX, TMIN and SAG (if used) may have to be set differently to optimize performance. Details of performance testing to optimize performance are given in the reference article.

Area and Count Limits - There are four controls for setting the upper and lower limits (UL and LL) for area and count. These controls should be set to optimize performance (see reference article). The control on the output of the count DAC (digital-to-analog converter) should be set so that at full count the upper limit may be set to a value greater than the comparator input voltage.

Focus Parameters

Integrated Optical Density - The front panel control "FOCUS IOD" sets the threshold density. For calibration there are two additional adjustments. First the integrator offset pot (10K) is set to compensate for offset in the integrator and/or its input. This is done by observing the integrator output when viewing blank background and adjusting the pot until the output remains constant as closely as possible during the entire TV field. An oscilloscope display should show a horizontal line (or nearly). After this adjustment, the offset of the output amplifier (MA741) should be set to give zero volts out when viewing blank background.

High Frequency - The gated amplifier (MC1545) offset control (1K) should be adjusted to give an output waveform which has a single baseline as viewed on an oscilloscope triggered every TV field. The output offset (2K) is adjusted to give zero volts out when viewing blank background.

Preventative Maintenance

No preventative maintenance is required except that operational checks should be performed at least weekly.

Diagnostic Aid

Performance Tests - The results of performance tests on the initial version of the system implemented on the research instrument (ALMS-II) can be considered typical and may be useful in determining the cause of some malfunctions. The performance tests and results, as described in the reference article (See Section V.A.3.) also detail the procedure one should utilize in optimizing system performance.

Panel Meters - The panel meters, previously described in section V.C., give a visual indication of the spread presence parameter or focus parameters. They may be used as an aid to determine the cause of a particular malfunction. The meter readings in spread detection mode should be within the preset limits for spread detection with a spread in view and out of the limits with background or an undivided nucleus in view. When viewing a spread image in the focus mode, both IOD and HF readings should peak out at the position of best visual focus and drop off on either side. If the IOD saturates (i.e., gives a reading greater than 10 volts), lower the IOD threshold. If HF saturates, check the offset of the output amplifier and readjust for zero with blank background in view. If saturation still occurs it will be necessary to lower the gain of the output amplifier by changing the feedback resistor.

Displays - The two displays, described in the Operation Section may be used as a diagnostic aid to:

a) Determine input video level and quality.
b) Graphically view threshold output.
c) Determine what threshold crossings are being counted as valid.

C. INTERACTIVE GRAYSCALE DISPLAY

Periodic Maintenance and Calibration

The Grayscale system should be inspected daily for cursor registration and weekly for linearity, focus and gray level resolution. Software cursor calibration is described in Section II.

The cursor registration is checked visually with the aid of the maintenance program. Starting with a clear target, crosses are requested, centered at various points on the display (particularly near the display edges) and the computer positioned cursor inspected for coincidence with the scan converter stored crosses. If the two do not align within limits the cursor gain and offset within the Hughes 639 scan converter should be adjusted per the instructions in the Hughes 639 manual.

The linearity and focus are checked by writing the multiburst patterns onto a cleared display and inspecting them visually. If required, the focus and/or linearity should be adjusted per the Hughes 639 manual.

The graylevel resolution is checked visually with the graylevel staircase patterns. Residual images should be cleared from the scan converter prior to writing the patterns.

The graylevel calibrations are performed mainly by the procedures set forth in the Hughes 639 manual. There are, however, two external adjustments, one within the GS Controller and one in the Scan Converter Interface, that affect the graylevel adjustments.

When initially calibrating the graylevel response the write unblanking signal in the GS Controller should be set to its minimum width. This signal is generated by the adjustable one shot, E45, shown on JPL drawing CALMS Grayscale C1, Sheet 1. The analog intensity gain should be set at its maximum (0.5 volts full scale). This is controlled by a 200 ohm potentiometer on the output of the Model 4020 DAC, shown on JPL drawing Operator System Control Module, Sheet 1. If the required graylevel response cannot be achieved when adjusting the Hughes 639 at these two external settings the settings should be altered.

If the scan converter is saturating toward the white end the video gain in the Scan converter Interface should be reduced. If the scan converter's full black to white range cannot be achieved the GS Controller's write unblanking should be re-calibrated for optimum results.

Diagnostic Aids: Table 9-1 lists some possible failure modes and recommended troubleshooting procedures.

TABLE 9-1

GRAYSCALE DISPLAY TROUBLESHOOTING GUIDE

Symptom A

Write mode operation commanded, no writing but an operation complete indication (GS BUSY rising and falling or a GS Operation Complete interrupt, if enabled).

Corrective Action A

1. Check all Grayscale interunit cabling.
2. Have the computer continuously issue write commands and check the write mode and unblanking signals from the source in the GS Controller to the scan converter.
3. Check the X and Y analog outputs to the scan converter.
4. Check the X and ΔY counters for proper loading and incrementing.
5. Check registers GSXWP and GSPC for proper content.
6. Check the intensity analog output to the scan converter.
7. Check the pixel intensity circuit.
8. Refer to the Hughes 639 Instruction Manual for further information.

Symptom B

Erase mode operation commanded, no erasing but an operation complete indication.

Corrective Action B

1. Execute a series of erase commands and check the erase mode and unblanking signals from their source in the GS Controller to the scan converter.
2. Manually clear the target and attempt a write mode operation. If unsuccessful go to Corrective Action A. If successful refer to the Hughes 639 Instruction Manual for further information.

Symptom C

Write mode operation commanded, no response and no operation complete indication. Erase mode operates correctly.

TABLE 9-1 (Continued)

Corrective Action C

1. After an attempted operation check the GS BUSY signal. If not true go to Corrective Action E, step 2. If true continue to step 2.
2. Check the microprogram address to see if it is in the correct range. If not, check the operation control bits circuit. If so, perform step 3.
3. By the microprocessor address and the timing diagram of Figure E-1 determine the anomalous signal condition(s), checking the signals from their source to their final destination.
4. Have the computer continuously issue write command sequences. The sequences should be approximately 20 milliseconds apart and be immediately preceeded by a Grayscale RESET command (write a i to bit 14 of register GSSC). Check the anomalous signal circuit(s) until the fault is found.

Symptom D

Erase mode operation commanded, no response and no operation complete indication. Write mode operates correctly.

Corrective Action D

Perform the steps of Corrective Action C, substituting erase mode signals for write mode signals where applicable.

Symptom E

No response or operation complete indication when either a write mode or erase mode operation is commanded.

Corrective Action E

1. Have the computer issue a Grayscale reset and then a write mode operation command. Check to see if GS BUSY is set and then check to see if the microprogram address is in the ocrrect range. If both GS BUSY is set and the address range is correct go to Corrective Action C, step 3. If either is incorrect proceed to step 2.
2. Have the computer cycle through issuances of Grayscale reset and a write mode operation command sequence. There should be approximately 20 milli-

TABLE 9-1 (Continued)

seconds from the write mode command sequence to the Grayscale reset command.

3. Verify that the Grayscale DMA Controller is being initialized correctly and is issuing the GO signal.
4. Verify that the M1710 is performing the computer handshaking and generating the Grayscale DAR strobes.
5. Verify that the Grayscale DARs are being loaded with the proper data.

Symptom F

Erase or write mode operation requested and performed but no operation complete interrupt received.

Corrective Action F

1. Verify that the interrupt request has been enabled by the computer.
2. Cycle through computer issuances of erase or write mode operation command sequences and verify that GS BUSY is rising and falling.
3. Trace the interrupt generation from the GS BUSY source, through the interrupt request logic to the interrupt generation logic on the M1710 card until the erroneous circuit is found.

Symptom G

Computer commands the cursor to move but no response.

Corrective Action G

1. Verify that the cursor is under computer control by checking bit 8 of register GSSC.
2. Verify that the cursor on signal is being sent to the Hughes 639 unit.
3. Request a known computer positioning of the cursor and verify that the GSXCP and GSYCP registers have been loaded with that position's digital value.
4. Verify that the position data is being transmitted through the X and Y multiplexers to the D/A deflection circuits in the scan converter interface.
5. Refer to the Hughes 639 Instruction Manual for further information.

TABLE 9-1 (Continued)

Symptom H

Cursor will not respond to operator commanded moves.

Corrective Action H

1. Verify that the cursor is under operator control by checking the indicator light on the Operator System Control panel.
2. Verify that the cursor on/off switch on the panel is on, and that the signal is going to the scan converter unit.
3. Verify that the cursor joystick pulses increment and decrement and decrement registers GSXCP and GSYCP.
4. Go to Corrective Action G, step 4.

Symptom I

A single-lamp indicator does not light up when commanded.

Corrective Action I

1. Check the signal input to the indicator. If true, replace the indicator.
2. Check the indicator's signal back towards its source in register OSID until an anomalous condition is discovered.
3. Have the computer repeatedly command the indicator on the check if its bit is being set in register OSID.

Symptom J

A numeric indicator does not display the proper number.

Corrective Action J

1. Have the computer attempt to load a known number into the indicator. Check the indicator's BCD and strobe inputs. If correct replace the indicator. If there is an anomaly, trace its circuit backwards to the source of the error.

D. HARDCOPY INTERFACE

Periodic Maintenance

No periodic maintenance is required for the HCI. The recorder, however, should be cleaned daily. Cleaning procedures and other periodic maintenance recommended for the recorder are found in the recorder manual section 5.

Calibration

Calibration consists primarily of adjusting the THRESHOLD and CONTRAST controls on the recorder to show all 16 gray levels on the hardcopy output. Operation of the controls is covered in Section II. Major changes in the setting of these controls should be needed only when changing to a different type of recording paper.

Diagnostic Aids

The major diagnostic aids available are the TEST mode in the HCI and CALIBRATE mode in the recorder. Use of the TEST mode in the HCI has been previously described. With the recorder in CALIBRATE and no test frame in progress, it should be possible to record a vertical step wedge frame by continuously depressing the START button on the recorder. Use of these two diagnostic aids should enable the malfunction to be isolated to wither the HCI or Recorder.

NASA — JPL — Coml, L.A., Calif.