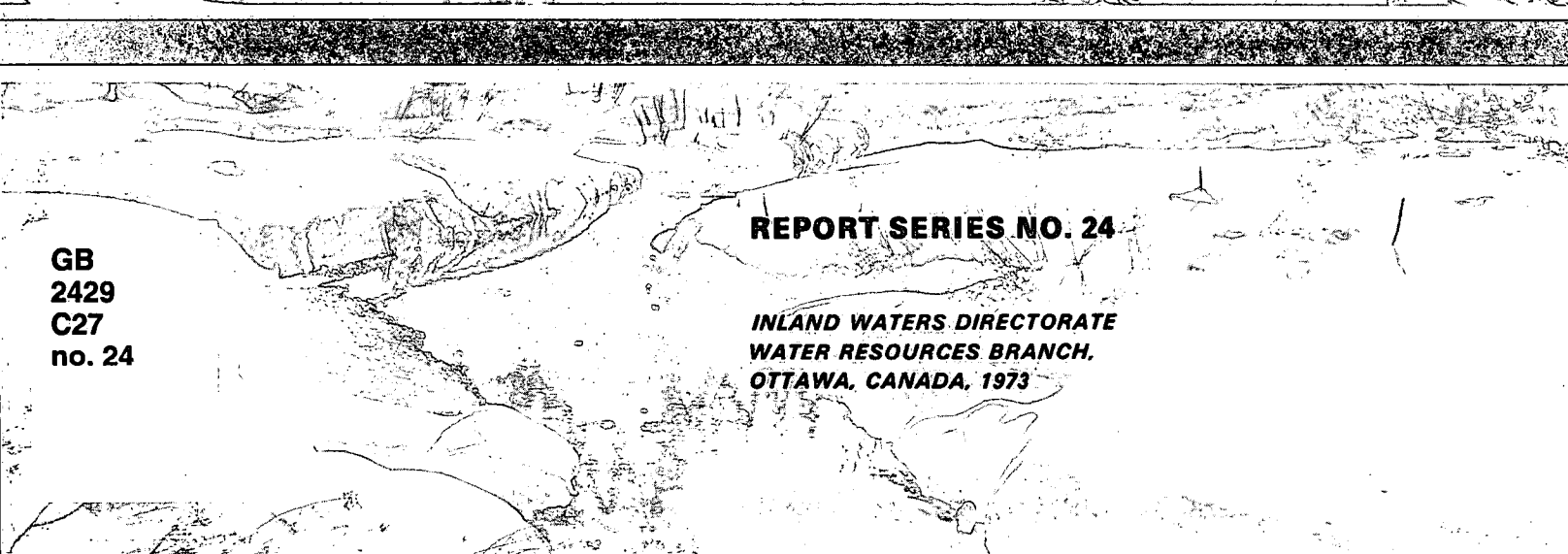
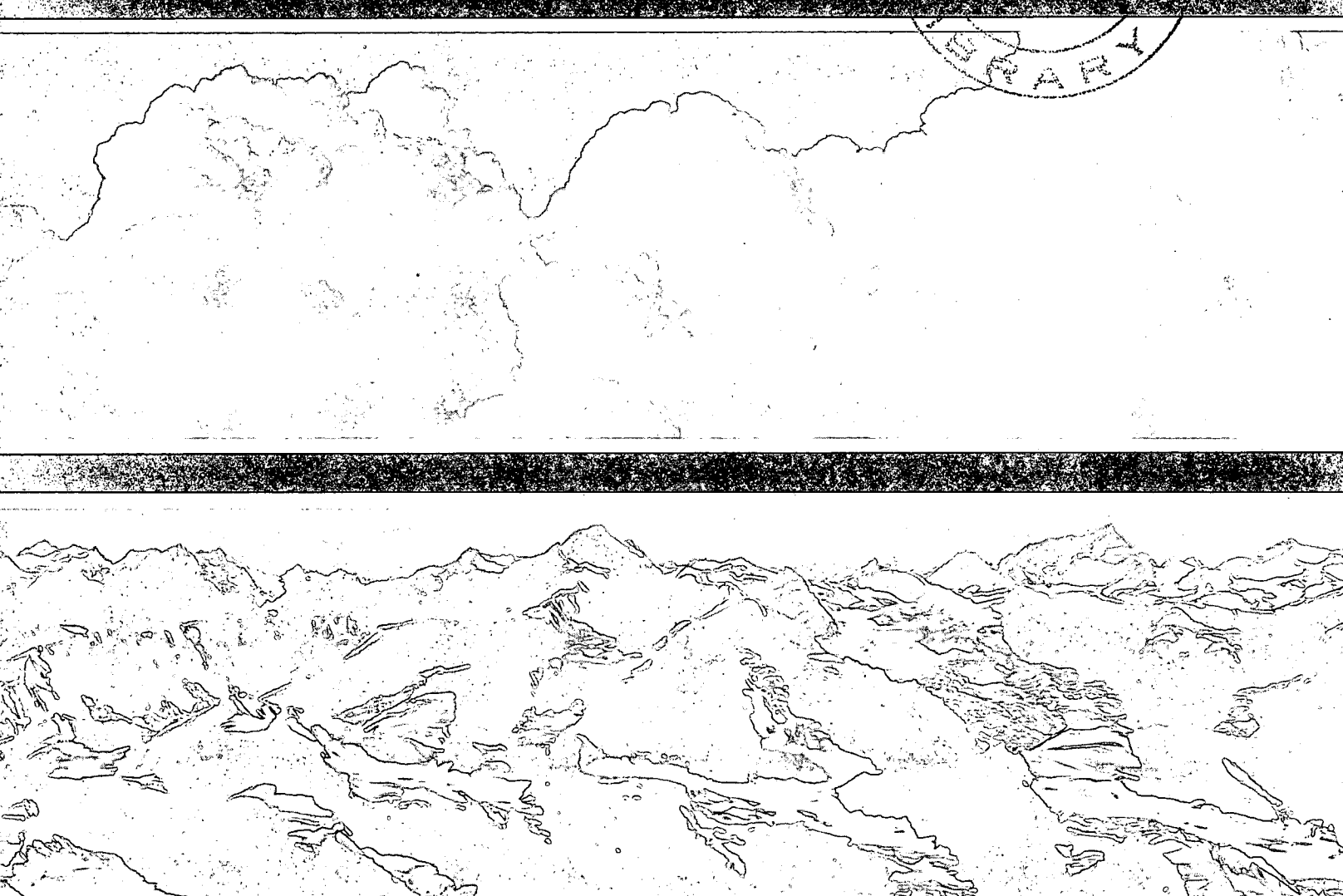
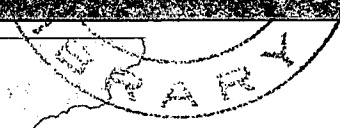




FOCAL on the PDP-9 Computer

S. H. Whitlow



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**INLAND WATERS DIRECTORATE
WATER RESOURCES BRANCH,
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Abstract

This report is designed to be an operating guide for running user programs on the Water Science Subdivision PDP-9 digital computer. It is to permit users with little or no computing background to run simple programs using the FOCAL (*F*ormula *C*ALculator or *F*ormulating *O*n-line *C*alculations in *A*lgebraic *L*anguage) conversational language. Since there is no specific guide supplied for FOCAL on PDP-9 computers, operating procedures have been gathered from various sources and are combined with techniques developed through usage to provide step-by-step direction.

A new external function, FDRA, is described which adds a straight line display capability to FOCAL. Directions are given to utilize this feature in user programs and an example, "Least-squares fit with scope display", is provided.

Introduction

A. THE ROLE OF A SMALL COMPUTER IN THE RESEARCH LABORATORY

Many physical-chemical experiments require mathematical processing of raw observations. The volume of data, the complexity of analysis, or the accuracy required often preclude the use of slide rule or calculator. On the other hand, the absence of individual control over large computers, the lack of flexibility, and the inherent time delays decrease the attractiveness of batch-processing at a large computer. A small in-house computer, therefore, has much to recommend itself in terms of convenience, speed and accuracy, and user control. The conversational programming languages permit the operator to readily perform detailed calculations, edit the data or modify the program. Accuracy and speed of calculation are the same as in very large computers, and operator intervention is possible wherever necessary. Also, the learning of basic programming and computer operations is facilitated by the interactive nature of the conversational language of a small computer.

In the Water Science Subdivision the PDP-9 computer is used for a variety of scientific calculations. These include analysis of X-ray diffraction, viscosity, density, conductivity, and chromatographic experiments. Often results are needed quickly for calibration purposes or as parameters in subsequent experiments; alternately, mathematical analysis may be used to derive final results and to establish statistical criteria. Much of the data processing is done by means of programs written within the Subdivision and it is anticipated that some of these computer programs of general interest will be described in a future report.

B. FOCAL AND THE PDP-9 COMPUTER

The *Programmed Data Processor-9* (PDP-9) computer is a fast, general purpose computer having a cycle time of 1 μ s and a word length of 18 bits. The computer was manufactured by the Digital Equipment Corporation which has also developed the FOCAL language. The standard peripheral devices are a high speed (300 cps) paper tape reader, a fast (50 cps) punch and a console teletype.

The Water Science PDP-9 computer has 16,384 (16K) words of ferrite memory storage. Other options include

automatic priority interrupt, power fail protection, an extended arithmetic element and a Tektronix RM503 oscilloscope display.

Considerable software for both programming and maintenance is supplied with the computer but most of this is not required by the user concerned only with FOCAL programming. The Water Science computer is operated with paper tape input and output under control of the Input/Output Monitor System. (Details of the I/O Monitor and any System tapes mentioned in this report can be found in the reference manuals 1-7.)

C. DIFFERENCES BETWEEN FOCAL-9 AND FOCAL-8

FOCAL has been primarily developed for the PDP-8 family of computers. For users familiar with these machines some differences will become apparent in operating FOCAL on the PDP-9. Fortunately, most differences are relatively minor and transparent to the user. The most important are summarized here:

1. FOCAL-9 assigns 3 characters to a variable name, thus AB1 and AB2 are not the same in FOCAL-9 but would be considered identical in FOCAL-8 which notes only the first two characters. This may cause slight difficulties in adapting FOCAL-8 programs.
2. FOCAL-9 does not print an equal sign (=) after internal computations as does FOCAL-8.
3. A comma or a space is not an acceptable terminator in FOCAL-9. RETURN or ALT MODE must signify the end of input data.
4. The leader on FOCAL-9 user programs is merely feed holes. FOCAL-8 programs with @ (300₈) leader code should be read in after the leader at the beginning of the program.
5. The longer word length and increased size of the PDP-9 relative to the PDP-8 permits increased accuracy (9 significant figures vs 6), more possible line group numbers (99 vs 32), larger permissible numbers ($\pm \sim 1 \times 10^{998}$ vs $\pm \sim 1 \times 10^{615}$) and of course, more memory ($\sim 10,000$ locations vs ~ 700 for a 4K PDP-8).

Running a Focal Program on the PDP-9 Computer

A. FLOW DIAGRAM

In this section instructions are given which will permit the user to run FOCAL programs on the computer. Figure 1 shows a flow diagram of the procedures to be followed to initiate the FOCAL System. In this diagram the directions

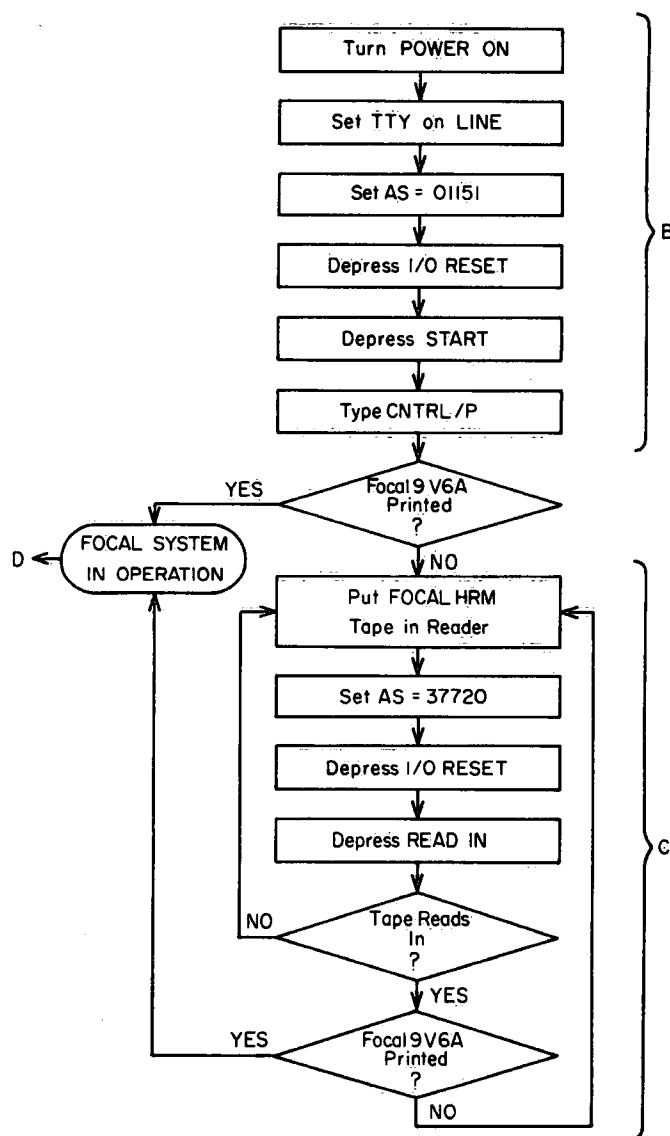


Figure 1. Flow diagram to initiate the FOCAL system. (B, C and D refer to the location of detailed explanations).

have been summarized in a concise manner to permit rapid operation; detailed explanations and clarification are given for each step in parts B, C, and D of this chapter.

B. INITIALIZING THE FOCAL SYSTEM

1. Turn the POWER switch on the right side of the console to the ON position.

2. Ensure that the switch on the front of the teletype (TTY) is on LINE. This means that signals typed on the keyboard go to the computer.

3. Place the starting address of FOCAL on the ADDRESS switches (AS). The address 01151 in octal (switches 8, 11, 12, 14 and 17 up, all others down) should be set on the switches numbered 3 to 17 on the centre left of the console. All the remaining white flip-flop switches should be down in the off position.

4. Depress I/O RESET and release. This clears all the interrupt flags and initializes the computer.

5. Depress START and release. The TTY should respond.

6. Type CTRL/P on the keyboard (i.e. hold the CONTROL key down while typing P). The TTY will print "FOCAL 9 V6A" and an asterisk if FOCAL is ready for use. Otherwise it is necessary to reload the FOCAL System tape (Section C).

C. LOADING THE FOCAL SYSTEM TAPE

A binary FOCAL System tape is available which can be loaded directly using the high-speed reader. (Preparation of this tape is described in Chapter 4.)

1. Place the FOCAL System tape in the high-speed reader located above the console and momentarily depress the white TAPE ADVANCE button on the reader to ensure that the tape is properly engaged. The tape should advance in the direction of the arrows and must be positioned so that some leader remains in front of the program.

2. Set the starting address, octal 37720, on the ADDRESS switches (switches numbered 4, 5, 6, 7, 8, 9, 10, 11 and 13 up and all the rest down).

3. Depress I/O RESET and release.
4. Depress READ IN and release. The tape should begin to advance past the reading head.
5. Ensure that the receiving bin does not overflow. This will normally require removing some of the tape from the receptacle during input. This may be accomplished by depressing the STOP button, removing the section of tape which has been read, and then depressing CONTINUE to reinitiate reading.
6. A version of the FOCAL System tape has been prepared in two parts for ease of handling. In loading this version, the computer will stop after reading the first section. Load the second tape in the reader, touch the TAPE ADVANCE button to engage, depress I/O RESET and then READ IN and the tape will advance again.
7. The FOCAL System is self-starting and at the conclusion of the read operation the TTY should print "FOCAL 9 V6A" and an asterisk indicating that FOCAL is now ready for use. If this does not happen, repeat the steps outlined in this section. If failure persists, additional assistance is required.

D. INPUT AND OUTPUT OF USER PROGRAMS

The conversational nature of FOCAL makes programming quite straightforward. The general techniques and instructions are well described in the various FOCAL manuals (8-10) and will not be discussed in this guide. However, the FOCAL input/output operations on the PDP-9 computer are not well documented and are given here. Operating directions for running a typical program (a least squares display program) are supplied in Chapter 3.

To load a user program

1. Type ERASE ALL or the equivalent abbreviation, E A to ensure that the program storage area is empty. After each of the following command instructions (or abbreviations) a RETURN must be typed. This terminates the input and causes the computer to act on the command. Note that if the abbreviated commands are used, a space must be typed after each character.
2. Place the tape in the high-speed reader and momentarily depress the TAPE ADVANCE button. Ensure that the beginning of the program has not advanced past the photoelectric sensor and that the arrows on the top of the tape point forward to the left.
3. Type LIBRARY IN ALL (L I A). The tape should be read into memory.
4. If an IOPS (Input/Output Programming System) error is generated and the tape does not advance it may be necessary to clear an interrupt flag. This may be done by typing CTRL/P and repeating these instructions.
5. Occasionally the tape will still not advance, in which case using a different "file name" (e.g., typing L I XXX) may help. This difficulty arises because the computer is designed to be file-orientated when used with a mass storage device. With magnetic tape or a disk, different programs can be called into the memory by their individual file names. Without mass storage, however, the names "ALL" or "XXX" are artificial and their continued use may occasionally cause errors.

To make a tape of a user program

1. It is assumed that the program is stored in the computer. (This can be verified by typing WRITE ALL (W A) and the program will be printed.)
2. Type LIBRARY OUT ALL (L O A). The high-speed punch will prepare a leader. Ensure that the tape is stacking properly in the receptacle.
3. Type LIBRARY WRITE (L W). The program will be punched.
4. Type LIBRARY CLOSE (L C). A trailing leader section will be generated. The new paper tape may now be torn off and used in the future to load the program.

E. RESTARTING PROCEDURE

1. The FOCAL System is ready for commands only when an asterisk has been generated.
2. Whenever there is an irregularity in operation, typing CTRL/P will generally force the program counter back to the starting address of FOCAL and cause the leading message to appear on the teletype. Typing CTRL/P may be used at any time to interrupt the computer and regenerate a fresh start.
3. More serious problems may be overcome by depressing the STOP key on the console and then proceeding as in Section B and if necessary C.
4. After use, the computer should be shut down by first depressing the STOP key and then turning OFF the POWER switch.

FDRA, a Straight Line Display Function

A. ADDING A FOCAL EXTERNAL FUNCTION

User defined functions can be incorporated into the FOCAL System by modifying the FNEW source program. The routine to be included must be written in MACRO, the symbolic assembly language of the PDP-9. This is then appended to the FNEW tape using the SYMBOLIC EDITOR and recompiled with the MACRO-9 Assembler. The resulting binary tape can then be loaded using the LINKING LOADER as described in Chapter 4. (The System programs mentioned are documented in the reference

manuals 2-7.)

The basic FNEW program (which is listed in Chapter 6 of the PDP-15 FOCAL Programming Manual) has been changed extensively from the Function Table onwards. The new function name, FDRA (FOCAL DRAW), was included in the Function Table and provisions were made to use the existing character processing and evaluation routines. In the revised FNEW tape all references to an Analog/Digital converter and the relay buffer have been deleted. A listing of the new portion of the revised FNEW tape is supplied in the Appendix.

```
//LINE DRAWING ROUTINE FOR THE DISPLAY
/  VERSION FOR FOCAL
/  COMMAND INSTRUCTIONS
/      SET Z =FDRA(N1,N2,N3)
//N1=0 FOR SETTING X AND Y BIAS TO BE
//      ADDED TO ALL POINTS DISPLAYED
//      N2 = X-BIAS
//      N3 = Y-BIAS
//      THE SPOT IS AUTOMATICALLY TURNED OFF
//      TO ALLOW THE DRAWING OF LINES
//N1=1 TURN THE SPOT ON
//      N2 AND N3 IGNORED
//N1=2 SET COORDINATES OF THE SECOND POINT FOR A STRAIGHT
//      LINE AND DRAW THE LINE - WHETHER A LINE IS ACTUALLY
//      DRAWN ON THE DISPLAY DEPENDS UPON WHETHER THE SPOT
//      HAD BEEN PREVIOUSLY TURNED ON
//      N2 = X-COORDINATE
//      N3 = Y-COORDINATE
//      THIS POINT DEFINES THE FIRST POINT OF THE NEXT
//      LINE TO BE DRAWN UNLESS THE USER PURPOSELY
//      CHANGES IT
//N1=3 TURN SPOT OFF
//      N2 AND N3 IGNORED
//N1=4 DRAW A LINE WITH THE SPOT ON
//      SPOT IS LEFT ON AFTER THE MOVE
//      N2 = X-COORDINATE
//      N3 = Y-COORDINATE
//N1=5 DRAW A LINE WITH SPOT OFF
//      SPOT IS LEFT OFF AFTER THE MOVE
//      N2 = X-COORDINATE
//      N3 = Y-COORDINATE
```

Figure 2. Control instructions for the line drawing function.

```

C FOCAL9 V6A
01.05 T " LINEAR LEAST-SQUARES FIT WITH SCOPE DISPLAY",!!
01.10 E
01.20 A "NUMBER OF POINTS ? ",NO,!
01.30 F I=1,NO;T %2.0, I;A X(I),Y(I),!
01.40 F I=1,NO;DO 4
01.50 S DE=X2*NO-SX*SX;S NU=XY*NO-SY*SX
01.60 S M=NU/DE;S B=(X2*SY-SX*XY)/DE
01.65 F I=1,NO;S YC(I)=M*X(I)+B
01.66 F I=1,NO;S SD=SD+(Y(I)-YC(I))2
01.67 S SD=FSQT(SD/(NO-2))
01.70 T %8.04,!, "SLOPE ",M," INTERCEPT ",B, " STD. DEV. ",SD,!!
01.73 S XBG=X(I);S XSM=X(I);S YBG=YC(I);S YSM=YC(I);S CT=1
01.75 F I=2,NO;DO 5
02.01 A "OBSERVED AND CALCULATED VALUES TO BE PRINTED ?",ANS,!
02.02 I (ANS-0YES)10.01,2.15,10.01
02.15 T !,"          X          YOBS          YCAL          DIFFERENCE ",!
02.20 F I=1,NO;T %2.0,I,%8.04,X(I),Y(I),YC(I)," ",Y(I)-YC(I),!
02.30 GOTO 10.01
04.10 S SX=SX+X(I);S X2=X2+X(I)*X(I)
04.20 S SY=SY+Y(I);S Y2=Y2+Y(I)*Y(I)
04.30 S XY=XY+X(I)*Y(I)
05.10 I (X(I)-XBG)5.2,5.2;S XBG=X(I)
05.20 I (XSM-X(I))5.3,5.3;S XSM=X(I)
05.30 I (Y(I)-YBG)5.4,5.4;S YBG=YC(I)
05.40 I (YSM-YC(I))5.5,5.5;S YSM=YC(I)
05.50 R
10.01 C DETERMINE OFFSETS AND SCALE
10.02 C WANT 0<XSM,YSM<50; 700<XBG,YBG<800
10.03 T !,"PLOT CALCULATIONS ARE BEGINNING "
10.05 S OSET=0;S SCALE=1;S YSET=0
10.10 I (XSM+OSET)10.2,10.2;I (50-(XSM+OSET))10.3,10.4,10.4
10.20 S OSET=OSET+1;GOTO 10.10
10.30 S OSET=OSET-1;GOTO 10.10
10.40 I ((XBG+OSET)*SCALE-700)10.5,10.5,10.45
10.45 I (800-(XBG+OSET)*SCALE)10.6,10.6,10.7
10.50 S SCALE=SCALE*1.25;GOTO 10.4
10.60 S SCALE=SCALE-.13;GOTO 10.4
10.70 I (YSM+YSET)10.71,10.71;I (50-(YSM+YSET))10.72,10.73,10.73
10.71 S YSET=YSET+1;GOTO 10.7
10.72 S YSET=YSET-1;GOTO 10.7
10.73 I ((YBG+YSET)*SCALE-800)10.76,10.76;S SCALE=SCALE*.9
10.74 GOTO 10.73
10.76 S YC(NO)=(YC(NO)+YSET)*SCALE;S B=(B+YSET)*SCALE
10.77 F I=1,NO;DO 13
10.80 T %5.02,"X-OFFSET",OSET," Y-OFFSET",YSET," SCALE",SCALE,!
10.85 GOTO 16.01
13.05 C PREPARE VALUES FOR PLOTTING
13.10 S X(I)=(X(I)+OSET)*SCALE
13.20 S Y(I)=(Y(I)+YSET)*SCALE
16.01 C DISPLAY SECTION
16.02 T "THE DISPLAY IS ON",!
16.06 S Z=FDRA(0,0,0)
16.07 S Z=FDRA(5,400,0);S Z=FDRA(4,0,0)
16.09 S Z=FDRA(5,0,400);S Z=FDRA(4,0,0)
16.20 S Z=FDRA(5,OSET*SCALE,B)
16.30 S Z=FDRA(4,X(NO),YC(NO));S Z=FDRA(3,0,0)
16.40 F I=1,NO;S Z=FDXY(X(I),Y(I))
16.50 GOTO 16.07

```

Figure 3. The least-squares display program listing.

B. THE DRAW FUNCTION, FDRA

The routine for drawing straight lines has been adapted for FOCAL from the DECUS Library Program 9-13 for FORTRAN and MACRO user programs written by J. Cox *et al.*, at the University of Tennessee and revised by J. Wyatt (II). Straight lines are drawn on the Tektronix RM503 display by illuminating every second point on the screen. The 4.5-inch diameter oscilloscope has a square grid with 1024 points along each axis so that the lines appear continuous. If lines are drawn beyond the grid there is a "wrap-around" effect and they reappear on the opposite side of the screen. The origin is taken to be at the bottom left corner of the screen with the X-axis horizontal and the Y-axis vertical.

The function is readily called by user programs; the command instructions are summarized in Figure 2. To use

the draw routine, it is only necessary to type "SET Z = FDRA (N1, N2, and N3)" where Z is a dummy variable and N1, N2 and N3 the desired parameters. It is advisable to preset the display buffer to zero by including the command: "SET Z = FDRA(0,0,0)", and usually it is necessary to incorporate command instructions in repeating loops so as to maintain the display.

C. LEAST-SQUARES FIT PROGRAM WITH SCOPE DISPLAY

A useful example of this external function is the following least-squares fit program with display listed in Figure 3. The program is a general one, accepting data points and solving for the best line by the standard least-squares technique. The data are then scaled (and off-set if necessary) to fill the oscilloscope screen. The same

```
GO
LINEAR LEAST-SQUARES FIT WITH SCOPE DISPLAY

NUMBER OF POINTS ? :8

1:1.83:1.586
2:5.84:2.443
3:7.02:2.772
4:8.25:3.244
5:13.20:4.441
6:18.75:5.67
7:22.10:6.420
8:26.50:7.776

SLOPE      0.2477 INTERCEPT      1.0900 STD. DEV.      0.1099

OBSERVED AND CALCULATED VALUES TO BE PRINTED?:YES

      X      YOBS      YCAL      DIFFERENCE
1      1.8300      1.5860      1.5432      0.0428
2      5.8400      2.4430      2.5364 -      0.0934
3      7.0200      2.7720      2.8287 -      0.0567
4      8.2500      3.2440      3.1333      0.1107
5     13.2000      4.4410      4.3593      0.0817
6     18.7500      5.6700      5.7339 -      0.0639
7     22.1000      6.4200      6.5637 -      0.1437
8     26.5000      7.7760      7.6535      0.1226

PLOT CALCULATIONS ARE BEGINNING
X-OFFSET  0.00 Y-OFFSET  0.00 SCALE  28.42
THE DISPLAY IS ON
↑P
FOCAL9 V6A
*
      (THE DISPLAY IS OFF)
```

Figure 4. Input and output of the least-squares display program.

scale is applied to both the X and Y values so that relative perspective is maintained. The axes are displayed together with the best line and the observed points. (The horizontal limits of the line are the Y-intercept and the last point to be entered). The display is useful to obtain an appreciation of the goodness of fit and to identify points deviating from the line. Because the cathode ray tube interfaced to the computer is not a storage oscilloscope, there is a considerable flicker even though the computer continually refreshes the screen. The display is maintained until the operator types CTRL/P and control is passed through the I/O Monitor to the starting address of FOCAL. For best viewing it is recommended that the oscilloscope be set with horizontal and vertical sensitivity of 0.5 or 1.0 V cm⁻¹.

D. RUNNING THE LEAST SQUARES DISPLAY PROGRAM

An example of the user action required to operate a typical FOCAL program is given for the least-squares display program; the teletype record in Figure 4 shows the "dialogue" between the computer and the user. Once the

paper tape containing the program has been loaded into the computer (as described in Part 2 D), the user types "GO" and depresses RETURN to start the program. In the example the computer types a heading and asks (by means of a colon) the number of points to be considered. In this case there are 8 data points so the character "8" is entered followed by ALT MODE. The X and Y values are then typed in by the user, each entry followed by an ALT MODE signifying the end of the number. When the data have been entered the computer outputs the slope, intercept, and standard deviation of the best line. Observed and calculated values are tabulated at the discretion of the user. In the example, "YES" was specified (followed by ALT MODE) so the observed and calculated values were output by the computer. If "NO" had been typed by the user, this output would have been omitted. The computer next performs the calculations required to plot and display the points and the best straight line. A message is typed and a bell sounded when the display has begun. The display is maintained until the user types CTRL/P and the program is halted. The message "FOCAL9 V6A" is typed signifying that the computer is ready to accept new instructions.

Preparing the FOCAL System Tape

Programs in the PDP-9 computer are loaded in core under control of the LINKING LOADER which allocates memory locations to main programs, subroutines and library functions. The procedure for loading the FOCAL System is described below and the teletype record including

```

LOADER V4A
> FOCAL, FNEW INCLUDING DRAW
  FOCAL  32121
↑P↑P
  FNEW   31632
↑P↑P
  PPA.   31041
↑P↑P
  .BH    31005
  DSORT  30715
  DSIN   30702
  DCOS   30661
  DATAN  30646
  DEXP   30633
  DLOG   30612
  .DD    30444
  .DB    30324
  .DE    30223
  .DF    30064
  .DC    30015
  .DA    27746
↑P↑P
  DOUBLE 27543
  REAL   26564
  .CB    26544
↑S↑S
FOCAL9 V6A
*↑P, T OR S?

>↑P
>
*↑P
FOCAL9 V6A
*
```

Figure 5. Loading record and memory map.

the memory map is given in Figure 5. The memory map lists the core locations (in octal) assigned to the various programs and functions.

1. The LINKING LOADER paper tape (L2ZD-PH) is loaded at 37720₈ using the high-speed reader (I/O RESET, READ IN).

2. The binary FOCAL system tape (FOCAL V6A KJ1C-PB) is placed in the reader and the names of the programs (FOCAL, FNEW) to be loaded are typed on the keyboard. Depressing the ALT MODE key initiates the read in.

3. The modified FNEW tape (binary version compiled by the MACRO-9 compiler) is put in next. Tape read in for this and subsequent tapes is initiated by typing CTRL/P after the ↑P signal from the computer.

4. It is next necessary to load the required device handlers and the appropriate library functions. This is done by loading sequentially the system library tapes 1, 4B and 5A (SYOA-PB, SY5E-PB and SY6D-PB). Library tape 1 supplies the teletype handler while tapes 4B and 5A provide the floating point arithmetic package and the trigonometric functions.

5. After loading the final library tape the computer signals ↑S. Typing CTRL/S transfers control to the starting address of FOCAL and the heading "FOCAL 9 V6A" and an asterisk are typed on the teletype. FOCAL is now ready for use.

6. To avoid the necessity of reloading all these tapes each time, an executable core load can be prepared. This essentially is a dump of the required memory locations which can be reloaded and will duplicate the previous memory contents. To generate a tape with this information, the System tape PUNCH 9 is loaded (I/O RESET and READ IN) at 37720₈. The computer responds with ↑P, T or S?. After typing CTRL/P the computer responds with >. A carriage return by the operator initiates punching of the output tape. This absolute core dump requires about a quarter of a box of tape so it is wise to ensure that there is sufficient paper tape in the punch reserve. The tape prepared in this manner can be used to regenerate the system as described in chapter 2.

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APPENDIX

MACRO Listing of the Line-Drawing Routine, FDRA

/TABLE OF NAMES OF EXTERNAL FUNCTIONS

```

/
.NEWF .NEWFE--1/2\777777+1 /TWO'S COMP COUNT OF NAMES
      .SIXBT /DXS/
      JMP SETX /SET X COORDINATE
      .SIXBT /DIS/
      JMP SETYI /SET Y COORDINATE AND INTENSIFY
      .SIXBT /DXY/
      JMP SETXYI /SET X AND Y AND INTENSIFY
      .SIXBT /DRA/
      JMP SETDRA /DRAW SUBROUTINE

.NEWFE=.
/
/IOT DEFINITIONS
/
DYL=700606 /LOAD Y COORDINATE
DXS=700546 /LOAD X COORDINATE AND INTENSIFY
DXC=700502
DYC=700602
/

      .EJECT
SETX JMS* .AX /SET X COORDINATE
      DAC XCOORD /SAVE
      JMP* EFUN3 /RETURN
SETYI JMS* .AX /SET Y COORDINATE
      DYL /LOAD REG WITH Y
      LAC XCOORD
      DXS /LOAD WITH X AND INTENSIFY
      JMP* EFUN3 /RETURN
SETXYI JMS* .AX /SET X COORDINATE
      DAC XCOORD /SAVE
      JMS GETARG
      JMP SETYI /NOW SAME AS FDIS
SETDRA JMS* .AX
      DAC NC
      JMS GETARG
      JMS* .AX
      DAC NX
      JMS GETARG
      JMS* .AX
      DAC NY
//MODIFIED DECUS 9-13
//LINE DRAWING ROUTINE FOR THE DISPLAY
/ VERSION FOR FOCAL
/
      SET Z =FDRA(N1,N2,N3)
//N1=0 FOR SETTING X AND Y BIAS TO BE
// ADDED TO ALL POINTS DISPLAYED
// N2 = X-BIAS
// N3 = Y-BIAS
// THE SPOT IS AUTOMATICALLY TURNED OFF
// TO ALLOW THE DRAWING OF LINES
//N1=1 TURN THE SPOT ON
// N2 AND N3 IGNORED

```



```

//N1=2 SET COORDINATES OF THE SECOND POINT FOR A STRAIGHT
// LINE AND DRAW THE LINE - WHETHER A LINE IS ACTUALLY
// DRAWN ON THE DISPLAY DEPENDS UPON WHETHER THE SPOT
// HAD BEEN PREVIOUSLY TURNED ON
// N2 = X-COORDINATE
// N3 = Y-COORDINATE
// THIS POINT DEFINES THE FIRST POINT OF THE NEXT
// LINE TO BE DRAWN UNLESS THE USER PURPOSELY
// CHANGES IT
//N1=3 TURN SPOT OFF
// N2 AND N3 IGNORED
//N1=4 DRAW A LINE WITH THE SPOT ON
// SPOT IS LEFT ON AFTER THE MOVE
// N2 = X-COORDINATE
// N3 = Y-COORDINATE
//N1=5 DRAW A LINE WITH SPOT OFF
// SPOT IS LEFT OFF AFTER THE MOVE
// N2 = X-COORDINATE
// N3 = Y-COORDINATE
/
/
X2=NX
Y2=NY
NPTS=NC

LAC NC
SPA
JMP* EFUN3
TAD LIT001
DAC FUNCT
FUNCT XX
JMP INIT /INITIALIZE; NC=0
JMP ENERGY /LIGHT SPOT ON; NC=1
JMP MOVE /MOVE THE SPOT; NC=2
JMP DEENER /LIGHT SPOT OFF; NC=3
JMP MOVE /MOVE WITH SPOT ON; NC=4
JMP MOVEUP /MOVE WITH SPOT OFF; NC=5
INIT DXC
DYC
LAC NX
DAC XBASE
LAC NY
DAC YBASE
DEENER LAC LIT002 /ALTER COMMAND TABLE TO NOT DISPLAY LINES
DAC FUNCT+3
JMP* EFUN3
ENERGY LAC LIT003 /ALTER COMMAND TABLE TO DISPLAY LINES
JMP DEENER+1
MOVEUP LAC NX /SET UP NEW FIRST X WITHOUT DISPLAY
CLL
LLSS 7 /* 128
DAC X1 /FIRST X
LAC NY /SET UP NEW FIRST Y WITHOUT DISPLAY
CLL
LLSS 7
DAC Y1 /FIRST Y
JMP DEENER /TURN SPOT OFF

```

```

MOVE    LAC NX  /GET X-COORDINATE
        CLL
        LLSS 7  /* 128
        DAC X2  /SECOND X
        LAC NY  /GET Y-COORDINATE
        CLL
        LLSS 7
        DAC Y2  /SECOND Y
        LAC X1
        CMA
        ADD X2
        DAC DIFFX          /TOTAL X DISTANCE TO MOVE
        ABS
        DAC TEM1
        LAC Y1
        CMA
        ADD Y2
        DAC DIFFY          /TOTAL Y DISTANCE TO MOVE
        ABS
        DAC TEM2
        CMA  /DETERMINE LARGER OF THE TWO DISTANCES
        ADD TEM1
        SPA
        JMP .+3
        LAC TEM1
        DAC TEM2
        LAC TEM2
        CLL
        LRSS 10 /DIVIDE BY (128*2)
        DAC TEM1          / SET UP AS DIVISOR FOR X AND Y INCREMENT
        DAC TEM2
        SNA
        LAC (1  / MINIMUM OF 1 POINT TO BE DISPLAYED
        TAD (1
        CMA
        DAC NPTS          /NUMBER OF POINTS TO MAKE UP THE LINE
/CALCULATE AND STORE DELTA X AND Y
        LAC DIFFX          / DETERMINE DELTA-X
        GSM
        IDIVS
TEM1     0
        LAC0
        DAC DIFFX          /DELTA-X
        LAC DIFFY          / DETERMINE DELTA-Y
        GSM
        IDIVS
TEM2     0
        LAC0
        DAC DIFFY          /DELTA-Y
/ DISPLAY LOOP
DISPLP  ISZ NPTS
        SKP
        JMP FINISH        / COMPLETE LINE DISPLAYED
        LAC X1  / X-COORDINATE
        CLL
        LRSS 7  / DIVIDE BY 128

```

```

TAD XBASE          / ADD X-BIAS
DAC TEM1
LAC Y1 / Y-COORDINATE
CLL
LRSS 7 / DIVIDE BY 128
TAD YBASE          / ADD Y-BIAS
DYL
LAC TEM1
DXS / DISPLAY POINT
LAC X1
ADD DIFFX / ADD DELTA-X
DAC X1 / NEXT POINT TO BE DISPLAYED
LAC Y1
ADD DIFFY / ADD DELTA-Y
DAC Y1 / NEXT POINT TO BE DISPLAYED
JMP DISPLP
FINISH LAC X2 / SET UP FIRST X FOR NEXT CALL
DAC X1
LAC Y2 / SET UP FIRST Y FOR NEXT CALL
DAC Y1
DXC / CLEAR SPOT FROM DISPLAY
DYC
JMP ENERGY
X1 0 / FIRST X
Y1 0 / FIRST Y
DIFFX 0 / DELTA X
DIFFY 0 / DELTA Y
XBASE 0 / X-BIAS
YBASE 0 /Y-BIAS
LIT001 JMP FUNCT+1
LIT002 JMP MOVEUP
LIT003 JMP MOVE
/
GETARG 0 /GET ARGUMENT
JMS* XSPNOR /SKIP SPACES
SAD (254 /IS IT A COMMA?
JMP .+3 /YES
.DEC
LAW 1 /NO - ??01 ERROR
.OCT
JMP* FUNERR /EXTERNAL FUNCTION ERROR
JMS* UTRA /SKIP COMMA
LAC EVAL
DAC .+2
JMS* XPUSHJ /CALL EXPRESSION EVALUATOR
XX
JMP* GETARG /RETURN
/
XCOORD 0 /X COORDINATE STORAGE
TEMP 0 /TEMPORARY STORAGE
NC 0
NX 0
NY 0
/
.END

```

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