UNIVERSITY OF CALIFORNIA

LICK OBSERVATORY TECHNICAL REPORTS

No. 1

THE LICK OBSERVATORY PDP 8/I COMPUTERS

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Needed: Disc time sharing mods.
: expand Eqn. 2
- Note that more function + overlay, ovrt.
- Add a note on extended Functions
- IFIX should not need XSTAT(,)

Santa Cruz, California
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ABSTRACT

This report describes the Lick Observatory PDP 8/I computer with special emphasis on the programming language used. The system described represents one way of providing astronomers with direct access to a flexible, interactive data acquisition and reduction system, at reasonable costs and without undue dependence on programming specialists. The expanded FOCAL language described in this report allows powerful programs to be prepared by people unwilling to invest a large amount of time learning the intricacies of small computer programming.

The first part of the report gives a general description of the computers, and will be of interest to those desiring to use the computers for standard data acquisition or reduction operations. The second part consists of a number of appendices that give more detailed information and will be of interest to programmers who may wish to expand or modify the system capabilities. Several of the more exotic special FOCAL commands are also given a detailed description in the appendices.

Appendix Z gives a summary of functions and commands that are available in the LICK version of the FOCAL language.

It is probable that updated versions (or additional pages for this version) will appear from time to time.

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THE LICK OBSERVATORY PDP 8/I COMPUTERS

I. Introduction

a) Description

Three PDP 8I computers have been installed at Lick Observatory, for use in data acquisition and in data reduction operations where continuous interaction between the computer and an astronomer or operator is desirable. One machine (A) is at the 120-inch telescope at Mt. Hamilton, the other two are used (B) with the microphotometer and (C) with the Gaertner Automatic Measuring Engine at the Santa Cruz Campus.

Each of the computers is equipped with an 8K 12 bit core memory, a 32K disk memory, dual "DECtapes" and single 9-level IBM compatible magnetic tapes, special sense switches and a teletype for interactive work, and fast multiply-divide hardware. Calcomp plotters and large screen memory oscilloscopes are provided for machines A and B. Machines A and B each have a "joystick" which allows a non-storing curser to be moved about on the memory oscilloscope, indicating points of interest to the computer similarly to the way in which a light-pen is used.

In addition each machine has special hardware interfaced to aid in its particular data gathering task, as well as a fast hardware "bootstrap" to allow rapid loading of programs.

b) Using the Computer

Each user of the machine will normally have his own magnetic tape (DECtape), which contains his programs and operating system. The hardware "bootstrap" circuit in the PDP-8 will automatically load the computer memory from the magnetic tape so that any special operating procedure by one user should not affect the behaviour of the machine for the next user.

DECtapes ("Operating" Tape) containing standard programs will also be kept available. These are regarded as public property and can be used by those who do not have their own programs or their own tapes. Copies of these can be made by those who want a private tape, or who want minor modifications of standard programs.

CAUTION: Operating tapes should be used with the "Write Lock" switch setting on the tape transport. If operations requiring writing of data on tape are to be done, use a private tape.

c) Programming the Computer

An exceptionally simple, easy to use program language called "FOCAL" (similar to BASIC) can be loaded into the computer from the DECtapes. Special commands have been added to make the language more suitable for our work and the new version has been named LICK FOCAL. A summary of the standard FOCAL commands is given in Appendix A, error diagnostics in Appendix B, and a list of special commands is given in Appendix Z. A number of manuals giving detailed descriptions of the language are available.*

d) Some Features of LICK FOCAL

- Conversational mode of operation.
- 10 digit precision, floating exponent 10^{-616} to 10^{+616}.†
- Programmable addressed storage of over 7000 10-digit floating point variables on the disk.
- Programmable storage of over 28,000 4-digit (<4096) word-addressable integers on the disk.
- Chaining commands that allow one program to call another from the DECtape. Subroutines may also be called from tape.
- Easy program-loading, and program-storage procedures.
- Programmable transfer of data between DISK and DECTAPE.
- LOG, EXP, SIN, COS, SQUARE ROOT† functions.
- External devices such as microphotometer, CRT display, chart recorder, disk, and tape are under FOCAL language control.
- Additional special FOCAL commands can be added to deal with new hardware, or to carry out special operations in machine language.

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*Copies of these manuals are available from Digital Equipment Corp., Mountain View.

1. Advanced FOCAL
2. Introduction to Programming (1969) - Chapter 9
3. Programming Languages (1970) - Part 2
4. Disk Monitor System

2 and 3 are available in the Lick reading room.

†Some functions: SIN, LOG etc., give only 6-digit precision.

e) Start-up Procedure

I. FOCAL User's

1. Turn on power switch (key).
2. Place an operating tape on left hand spool of DECtape transport #8. Be sure only one tape transport is selected to unit 8.
3. Set tape switches to write-lock, local. Press button under right arrow for about 5 seconds to move tape past the "end zone".
4. Bootstrap procedure: on computer console, set address 200 (marked with red dot). Press "STOP". Set all other switches to zero. Set DECtape switch to "REMOTE"!
   Press "LOAD ADD"(ress)
   Press "DEP"(osit)
   Press "LOAD ADD"(ress)
5. Press lucite "bootstrap" button on left side of the computer. Check that the teletype is "ON-LINE". Press "START".
6. Tape will spin for a few seconds, the disk contents will be checked for parity errors, rewritten if need be, and the teletype will print "*". FOCAL is now loaded and ready for use. If a standard program is to be used, type GO, press return key, and respond to questions on the teletype.

II. Programming

a) Introduction

The programming system has been carefully designed so that any user can readily prepare his own programs, or add to an existing program. This can be done at several levels of complexity:

- FOCAL language programs can be written, or existing ones can be modified, using the fairly powerful FOCAL commands described in this report.
- Additional FOCAL commands can be prepared and made available on a particular operating tape, without modifying any of the existing system. (See Appendix N)
- FOCAL commands in the system can be deleted and replaced by others more appropriate to a specific application. (See Appendix M)
- Stand-alone machine language programs can be prepared for extremely difficult applications.

b) Writing a FOCAL Program

After the start-up procedure has been completed, a FOCAL program can be prepared by typing it on the teletype.

For a new program, first type "ERASE ALL",* then type "WRITE", to be sure that part of another program is not already present. To add to program N already on the program tape, first type "X CALL(N)", then type the additional instructions (or modifications).

-Note that FOCAL only recognizes a typed instruction when the "Return" key is pressed.

c) Saving a FOCAL Program on DECtape

After a program has been entered into the computer, it can be stored on DECtape for future use.

1. Set DECtape #8 to WRITE ENABLED
2. Type X FILE(N)[Return]; where N is a program number between 0 and 25.
   (If no data are to be stored on the tape, N may be as high as 168.)
3. The teletype will print the last address used for text storage. If a program number N already exists on the tape, the teletype will type OK?, unless that program has just been called from tape. If the previous program (or perhaps old data on the tape) is to be overwritten, type "Y". To avoid writing, type "N"(o), or press CTRL-C.
4. To recall the Program, type X CALL(N)[Return].
5. To recall it and start automatically at subroutine S, type X CALL(N,S)[Return].

*CAUTION: If a non-existent program is inadvertently called, FOCAL becomes deranged, and can only be cured by calling a real program, or by repeating the bootstrap operation. Attempts to ERASE, MODIFY, or ADD TEXT will lead to total confusion.

"CAUTION: A problem occurs if any line xx.63 is modified. To change such a line, erase it and retype the whole line." Digital Software News, June 1972.

d) Storage on DISK and DECtape.

The disk and DECtape can be used for storage of both programs and data. In order to avoid possible loss of data or programs, and yet make fullest use of the available storage areas it is important to understand how storage areas are allocated.

The disk and DECtape are subdivided into "blocks", each of which contain 129 12-bit computer words. The disk has 253 (374 octal) blocks while each tape has 1474 (2702 octal) blocks. Each block of tape can be addressed and modified without changing any other block. Each word on the disk can be independently modified.

The FOCAL system reserves part of the tape for program storage and allows the user to allocate the remainder of the tape to either data storage or program storage. The tape utilization is as follows:

Block No.			
Octal	Decimal		Allocation
0	0	:	DECtape Bootstrap
1-37	1-31	:	FOCAL Field 1
40-71	32-57	:	Overlay programs for top (24) 26 ? blocks of disk
72-131	58-89	:	FOCAL Field Ø
132-133	90-91	:	Free
134-157	92-111	:	X NAME(N) program storage
160-477	112-319	:	Programs 0-25 (8 blocks per program)
500-2700	32-1472	:	Data

On the disk, blocks 0-225 are available for data, the rest are used for machine language program overlays.

(See also Appendix C)

e) Copying DECtapes

It is sometimes necessary to copy all or parts of a program tape, sometimes onto a segment of another program tape. The FOCAL command L will start a copying program whose options are listed by the teletype. The options available are listed below. The copy routine resides in an area of the core memory that can be written over by other FOCAL commands, so copying should only be attempted immediately following a bootstrap operation. If operations such as X CALL( ) or X PULL(N,1) have been used, the L command will be ignored.

```
*L
TAPE COPIER
PRESS CTRL-P TO BYPASS PRINTOUT.
0:EXIT.
1:STORE THIS FOCAL ON TAPE 8.

COPY FROM TAPE 8 TO TAPE 7:
2:PROGRAMS 0--25.
3:PROGRAMS 0-49.
4:NAMES 1--5.
5:ALL FOCAL,NAMES AND PROG.0--49.
6:SELECTED NAME.
7:SELECTED PROGRAMS.
8:COPY THE WHOLE TAPE.
9:COPY FOCAL,NAMES AND INSERTS.
OPTION CODE:
```

f) Updating FOCAL Operating Tapes

There are several versions of LICK FOCAL, each containing commands suitable to particular operations such as microphotometry, image tube scanner operations, etc. The version is indicated by a code printed whenever the command "WRITE" is used. Revisions are indicated by a number indicating the year, and a letter showing the particular revision. Thus the heading LICK FOCAL SCN72-Q indicates revision Q, in 1972, of the version of FOCAL dedicated to operating the scanner system.

Often it is desirable to store a revised version of FOCAL on a program tape without changing the programs:

> Bootstrap the new version into the computer, put the old program tape on tape unit 8, and type L (Return). When the teletype types OPTION: type 1. The FOCAL system currently in the computer, and whatever overlays are on the disk, will be stored on the program tape, without disturbing either the programs or any of the X NAME(-) overlays.

g) Special Commands for FOCAL

The FOCAL language, as developed by Digital Equipment Corp., is designed primarily for mathematical manipulation, using a teletype as the input-output for the computer. The arithmetic is done by a software floating-point program, and almost no provision is included for interaction with special devices and with the magnetic tapes and disk. However, provision was made for the addition of special machine language subroutines which can be called by FOCAL commands and which can return numbers to the FOCAL arithmetic routines.

A considerable number of such subroutines have been developed to allow convenient interaction with the disk, DECtape, memory oscilloscope and numerous special devices.

The floating-point arithmetic done by FOCAL is inconveniently slow for some iterative data processing operations, where identical operations must be done on several thousand data words. Since FOCAL is an interpretive rather than a compiler language, several milliseconds are used just to start each instruction and multiply or divide may use 30 msec. A number of special instructions have been developed which carry out mathematical operations at high speed in machine language on large arrays of data for a single FOCAL command. In many instances, the time required to manipulate a data array is reduced from several minutes to a few seconds using these commands.

CAUTION: FOCAL does its arithmetic operations in floating-point arithmetic, with 10 digit precision. Most of the special data-handling operations use fixed point arithmetic and convert all input arguments to integer values.

h) Machine Language Program Preparation (See also Appendix E, M,N)

Machine language programs are prepared by using a program called EDIT, to store a symbolic language source text on the disk. A program called PALP is then used to assemble the source text into a binary program which can be loaded into the computer by a program called LOAD.

A "DISK MONITOR SYSTEM" which is found on "Source" tapes (but not on ordinary "Operating" tapes) allows manipulation of programs on both disk and DECtape, and can be used to control the editing, assembly, loading, storage and running of machine language programs on either the disk or DECtape.

The operations are very much faster and more convenient using the disk, but it is convenient to use the tapes for permanent storage, so programs have been written that allow the entire disk content to be copied onto a DECtape and later written back onto the disk. The program PUTT will store a disk image as files Ø,1,2,3,4 on a DECtape, while program GETT will reload the disk from one of these files.

One bootstraps the DECtape monitor, uses GETT to recall a disk image from the tape, then uses program DISC to enter the disk monitor. After editing, assembling etc. program PUTT stores the current version of the disk on tape, and program TAPE will recall the DECtape monitor.

Since the DECtape monitor and PUTT use the same tape (for convenience), and since the DECtape monitor can write over the section of tape used by "PUTT", some thought must be given to how the space on a particular tape is to be used.

The DECtape monitor has been modified (by changing block$(203)_8$ in the STORAGE ALLOCATION MAP), to make blocks beyond block $(1277)_8$ be marked as full. Thus the monitor cannot access the area used by PUTT for files 2,3 and 4.

CAUTION: Program PUTT can store disk images in files Ø and 1. The area used by these two files is accessible to the tape monitor. Files Ø and 1 should only be used on tapes where the tape monitor has only a few programs in the directory, and where at least 1000 free blocks are indicated when PIP is used to print out the directory.

The final form of this data system owes much to the advice and suggestions provided by numerous graduate students and staff members at Lick Observatory. Several people, most notably J. A. Baldwin, G. Cayrel, G. H. Herbig, and E. J. Wampler have helped by using the equipment heavily and providing detailed reports of difficulties encountered.

T. Sarbin, of Digital Equipment Corp. provided invaluable advice on the possibilities for modifications of the FOCAL language.

Much of the special electronics hardware attached to the computers has been developed in the Lick electronics shop under T. P. Ricketts.

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APPENDIX A

FOCAL COMMAND SUMMARY

Command	Abbr	Example of Form	Explanation
TYPE	T	TYPE FSQT (AL ↑ 3+FSQT (B))	Evaluates expression, types out result in current output format.
		TYPE "TEXT STRING"!	Types text. Use ! to generate carriage return line feed.
WRITE	W	WRITE ALL	FOCAL prints the entire indirect program.
		WRITE 1	FOCAL types out all group 1 lines.
		WRITE 1.1	FOCAL prints line 1.1
IF	I	IF (X) 1.2,1.3,1.4;	Where X is identifier or expression.

Control is transferred to the first, second, or third line number if (X) is less than, equal to, or greater than zero respectively. If the semicolon is encountered prematurely then the remainder of the line is executed.

MODIFY	M	MODIFY 1.15	Enables editing of characters on line 1.15

The next character typed becomes the search character. FOCAL will position itself after the search character; then the user may

q a. type new text, or
b. form-feed to go to the next occurrence, or
c. bell to change the search character, or
d. rubout to delete backwards, or
e. left arrow to kill backwards, or
f. carriage return to end the line, or
g. line-feed to save the rest of the line.

N. B. Do not attempt to modify any line numbered XX.63

QUIT	Q	QUIT or * or control-C	Returns control to user.
RETURN	R	RETURN	Terminates DO subroutines
SET	S	SET A = 5/B * SCALE(3)	Substitution statement
ASK	A	ASK ALPHA (I + 2 * J)	FOCAL types a colon for each variable; the user types a value to define each variable.

Command	Abbr	Example of Form	Explanation
COMMENT	C	C - compute area	If a line begins with the letter C, the remainder of the line will be ignored.
CONTINUE	C	C - ignore temporarily	
DO	D	DO 4.14	Execute line 4.14; return
		DO 4	Execute all group 4 lines, return when group is expanded or when a RETURN is encountered.
		DO ALL	Execute entire indirect text as a subroutine.
ERASE	E	ERASE	Erases the symbol table.
		ERASE 2	Erases all group 2 lines.
		ERASE 2.1	Deletes line 2.1.
		ERASE ALL	Deletes all user text.
FOR	F	FOR I = x,y,z; TYPE I	The command string following the semicolon is executed for each value; x,y,z are constants, variables, or expressions. x=initial value of I, y=value added to I until I is greater than z. y is assumed =1 if omitted.
GO	G	GO	Starts indirect program at lowest numbered line number.
GOTO	G	GOTO 3.4	Starts indirect program at line 3.4

NB - No FTRN
~~ALGEBRAN~~

C - The [redacted] Functions are

FSQT ( ) - Square Root
FABS ( ) - Absolute Value
FSGN ( ) - Sign Part of the Expression
FITR ( ) - Integer Part of the Expression
[redacted]
FEXP ( ) - Natural Base to the Power
FSIN ( ) and - FCOS ( ), [redacted] - Trig Functions
FLOG ( ) - Naperian Log
[redacted]

Computed GOTO: X GO(S, L) go to subroutine S, line L

Computed DO X DO(S, L) do line L, subroutine S.
X DO(S) do subroutine S.

APPENDIX B

ERROR DIAGNOSTICS*

Table B-1
Error Diagnostics of FOCAL, 1969

Location	Code		Meaning
	?00.00		Manual Start given from console.
	?01.00		Interrupt from keyboard via control-C.
0250	?01.40		Illegal step or line number used.
0316	?01.78		Group number is too large.
0340	?01.96		Double periods found in a line number.
0351	?01.:5		Line number is too large.
0362	?01.;4		Group zero is an illegal line number.
0440	?02.32		Nonexistant Group referenced by 'DO'.
0464	?02.52		Nonexistant line referenced by 'DO'.
0517	?02.79		Storage was filled by push-down list.
0605	?03.05		Nonexistant line used after 'GOTO' or 'IF'.
0634	?03.28	04:3	Illegal command used. Line too long
1047	?04.34		Left of "=" in error in 'FOR' or 'SET'.
1064	?04.52		Excess right terminators encountered.
1074	?04.60		Illegal terminator in 'FOR' command.
1147	?04.:3	05:1	Missing argument in Display command. Program too long.
1260	?05.48		Bad argument to 'MODIFY'.
1406	?06.06		Illegal use of function or number.
1466	?06.54		Storage is filled by variables.
1626	?07.22		Operator missing in expression or double 'E'.
1646	?07.38		No operator used before parenthesis.
1755	?07.:9		No argument given after function call.
1764	?07.;6		Illegal function name or double operators used.
2057	?08.47		Parenthesis do not match.
2213	?09.11		Bad argument in 'ERASE'.
2551	?10.:5		Storage was filled by text.
2643	?11.35		Input buffer has overflowed.
5042	?20.34		Logarithm of zero requested.
5644	?23.36		Literal number is too large.
6543	?26.99	27.24	↑ Power is too large or negative. Chain nested too
7111	?28.73		Division by zero requested. deep.
7405	?30.05		Imaginary square roots required.
	?31.<7		Illegal character, unavailable command, or unavailable function used.

*If push down list overflows, try - Type $ to see if unwanted variables are present. Use ERASE, to remove variables, but retain the program.

- When reading a program from paper tape ?11.35 diagnostic can be avoided by use of X STAT(1,980), command, which uses CRT for output listing, avoiding the teletype buffer problem.

APPENDIX C

Utilization of Dectape by Lick FOCAL

The FOCAL system, plus 26 FOCAL language programs, plus 5 user-added instruction sets, plus 18-4096 channel scans can be stored on one Dectape with no overlap.

Additional instruction sets beyond #5 can be added at the cost of erasing programs starting at program Ø, where two instruction sets use the space assigned to one program. Additional programs beyond #25 can be added at the cost of erasing data scans, starting at scan #Ø, where 8 programs use the space assigned to one scan.

A number of blocks within the FOCAL system itself are initially unused and can (with care) be used to store special tables etc. There are a total of 64 unused 12-bit words associated with each data scan. These may be used for storage of identification information etc.

The following page shows the exact location of programs, data, and unused space on a Dectape. The "scans" and "records" referred to are associated with data for the Image Tube Scanner.

DECTAPE SPACE ALLOCATION

BLOCK NO.																
OCTAL	0	1 --- 14		15 --- 27		30 ---37		40 ---- 71		72 --- 106		107 -- 113		114 --- 131		132, 133
DECIMAL	0	1	12	13	23	24	31	32	57	58	70	71	75	76	89	90 91
		Boot strap	FOCAL 10000- 13014		13015 -15627		FOCAL 15630 -17777		DISC OVERLAYS		FOCAL 0- 3177		FREE		FOCAL 4600-7577		FREE

*Blocks below $320_{(10)}$ can be accessed, using negative arguments in MPUT, MSAV, MTAK, MGET.

CAUTION - Program space is unprotected aginst negative arguments!!

OCTAL	134 --------- 157	160 ---- 477	500 ------- 2700
DECIMAL	92 --------- 111	112 ---- 319	320 ------- 1470
	X NAME(-)	X CALL(-)	X MGET(-); MSAV( )
	5 User generated overlays for special FOCAL commands	Focal text programs 0 -- 25	18 SCANS, each having 8 x 512 24-bit word records(#0--#143)*
			X MPUT; MTAK( ) 1151 x(129-12 bit word records or blocks) (#0-----# 1150

*Detail of one 8-block record [512 24 bit words]

Block	328	329	330	331	331	332	333	334	335	
Word	0---128	0---128	0- 128	0- 124	~~121~~ 125 -128	0-128	0--128	0--128	0--120	121--128
	512 12-Bit words of data; least significant 12 bits.				512 12-Bit words of data; most significant 12 bits.					Special I.D.etc.

*- Scanner System

APPENDIX D

Use of FOCAL System I - 0 Subroutines

The input-output subroutines provided in LICK FOCAL should be used by any machine language program that needs to transfer data to and from Disk, DECtape and Teletype.

A. Teletype

- JMS I CRLFX will produce a carriage return, line feed.

- TAD ASCII1 /ASCII teletype character .8 bit
  JMS I TYPEX

  will type the character whose ASCII code is in the accumulator

- JMS I MESAGX
  TEXT "ALPHA-NUMERIC MESSAGE"

  will type the message following 'TEXT'. The PALP assembler converts messages prefaced by 'TEXT' to suitable machine language code. A 6 bit Ø is used by the assembler to indicate end-of-message.

- TAD NUMBER
  JMS I OCTPNX

  will print the contents of the accumulator as a 4 octal-digit number.

Notes

All of these routines act only on the teletype, and will not produce output to the CRT.

- All routines use JMS I TYPEX for each character.
- JMS I TYPEX will always wait until any FOCAL message is complete before starting to use the teletype. [unless C(INTRUP) = 0. See interrupt note.] Page D4.
- Unless otherwise specified above, the accumulator should be cleared before any of these operations. The accumulator will always be zero when the subroutine returns control to the calling program.

To read information from the teletype keyboard, use the following routine

```
IOF
KSF
JMP .-1
KRB
```

Core addresses are defined in the sub-listing "CONØ"(Field 1) [see App. 2]

CRLFX	-	130
TYPEX	-	127
MESAGX	-	22
OCTPNX	-	136
INTRUP	-	126
KILALL	-	132

B. Disk

- JMS I GETWRX fills ARG2 with the disk word whose block number is in ARG3 and whose word number is in ARG4.
- JMS I PUTWRX - puts the content of ARG2 into the disk word whose word address is in ARG3 and block address is in ARG4.
- IF ARG3, ARG4 are zero the next disk work is accessed.
- TAD FUNC (2 to write, 0 to read.)
  JMS I DISCX
  JMP.-2 /DISK ERROR (Teletype prints "DISK"?)*

  Will read or write the disk to or from core.

*Disk ERRORS will always return control to Focal via KILALL

C. Tape

- TAD FUNC /20 to write, 0 to read.
  JMS I DTAPX
  JMP .-2 /tape error (Teletype prints "TAPE"?)

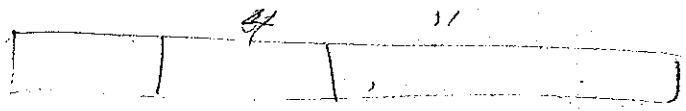
  will read or write the DECtape to or from core.

  Any number of words can be read, but an integral number of 129 word blocks will always be written.

Notes

The number of words, core addresses, tape and disk addresses are determined by presetting several words in Field 1.

Word	Name	Description
23	DDCORE	First core address
24	DDWCNT	Negative word count e.g. 7771 for 7 words
25	DISADD	First disk word address in a 4K segment.
26	DSFELD	-Core field: 10- field 1. 00 - Field Ø -Disk segment 0,100,200---700: selects 8 4K segments. (e.g. for disc segment 100 and field 1: C(DSFELD)=110)
27	DTBLOK	First DECtape block
30	DTUNIT	DECtape unit 7 (e.g. 7000 for unit)



Two other words, DISEND and DTEST, control the area of the disk available to the program. These should not be changed!

115	GETWRX - Get a word	20 - DISCX	disk routine pointer
120	PUTWRX - Save a word	21 - DTAPX	tape routine pointer

One block of the disk is held in a core buffer, to reduce the number of calls to the disk. To be sure that this block is actually on the disk use: JMS I BWRITX. If disk contents are being changed by JMS I DISCX, the core buffer may be obsoleted:

```
Use:   JMS I BWRITX      /Location 10137
       CLA CMA           /A non-existent block number
       DCA BLOKIN        /Location 10116
```

JMS I BWRITX copies any updating in the core buffer onto the disk.

BLOKIN is the number of the block now in core.

A word BWTEST, at 10033 is non-zero whenever updating of the core buffer has not been copied to the disk.

Notes on use of Interrupt by FOCAL Subroutines

The interrupt is left on almost all the time in LICK FOCAL 73. Subroutines will be started with interrupt on. Interrupts from the Teletype, Disk, DECtape and Clock can be properly handled.

During program overlay, an interval of about 0.1 sec will occur during which interrupts are turned off. This is needed to insure that an overlay cannot be stopped half-way through by CRTL-C (which could 'bomb' the system in core, and force reloading). When DECtape is being written or read, the interrupt is off for an interval of about $\frac{N}{15000}$ seconds, where N is the number of words being transferred.

Some machine language programs must run with interrupt off. They should use the machine instruction IOF. If system I/O routines are to be used with-

out interrupt, set word INTRUP (10126) to Ø. [Pressing the teletype CTRL and C should always return control of the computer to the keyboard. Programs which operate with interrupt disabled should include JMS I FLAGX (which tests the keyboard and other flags) in any sequence requiring more than a second, or provide a keyboard test for CTRL-C within the program.]

The computer clock can be used as an interrupting device, if an exit pointer is placed at "CLOKGO" (10007) and a time interval placed as a negative number in CLKCNT (10113). When the clock times out, a JMS I CLOKGO results. The programmer must insure that his clock service program does not get overlaid in the meantime, and remember that overlays from the disk, and use of DECtape, will produce intervals of up to 1/10 sec when no interrupt can occur. Programmable-interval clocks are provided for computers at the AME and at the 120-inch telescope. A clock with a period of 1/6 the power line period (2.78 msec) is provided at the microphotometer.

Routines triggered by the clock should not attempt to use the DECtape or disk. Since the clock routine is called from subroutine "FLAGS", any attempt by a clock service routine to use JMS I FLAGX will produce a closed loop, which can only be stopped by pressing CRTL-C.

Tape Reproduction

A program "DUPL" can be used to duplicate all or part of a tape. In order to copy a whole tape, respond to the program's request by typing 0, 2700. Set the "output" tape transport to 1, write enabled.

The tape is copied in segments, then Tape 1 rewinds and is read to test for writing errors that would cause parity faults. At the end, the monitor is recalled from Tape 8.

APPENDIX E

Programmer's Note

Storage on Source Tapes

The Dectape Monitor system stores programs on the tape, starting with the lowest numbered free block (the first few blocks are used up storing the Monitor itself). The disk monitor is stored on a tape by program "PUTT" which copies the whole disk onto a selected area of the tape. The tape can hold up to 5 copies of the disk; each copy is called a "file" and files are numbered 0 - 4. The file number merely determines which section of the tape will be used.

FILE NUMBER	TAPE BLOCKS (OCTAL)
0	300 - 675
1	700 - 1275
2	1300 - 1675
3	1700 - 2275
4	2300-- 2675

Blocks 0 - 277 are used only for program storage and cannot be over-written by PUTT. Program PUTT will always test the first 20 blocks of any file before writing on it and request confirmation if any non-zero word is found, even when rewriting a file just copied to the disk for editing.

The Dectape monitor will use successive blocks of tape for storage as new programs are added. Thus data stored in file Ø could be over-written by a new program added to the tape, and no warning would be given.

Program PIP can be used to determine how many blocks have been taken by the monitor. Type PIP (return) OPT-L (return) IN-DØ: (return). PIP types the number of free blocks, and the names of all stored programs. Restart the monitor by pressing CTRL and typing C.

APPENDIX F

Explanation of the "FUNC" Command in FOCAL (Microphotometer)

Introduction

The command "Set Y = FUNC(B,W)" can be used to calculate "Y" as a function of the content of disk word W, Block B. The function Y = f(x) is first tabulated for the 129 values of Y when X = 0, 8, 16, ---1024. Then values of X between 0 and 1024, stored on the disk, can be rapidly converted to the corresponding value of Y. This table look-up technique is a method of obtaining faster response from FOCAL. It also simplifies the use of functions which do not have a simple mathematical description.

Procedure

Values Yi = f(Xi) are calculated for i = 0,--128, (where XØ=0, X1=8, X2 = 16 --- X129 = 1Ø24) and stored on words 0 to 128 of any disc block NC by successive commands X PUT(NC, i, Yi). Then the command "X SET(NC,NC)" will place that table in the appropriate buffer area of the computer's core memory. Further commands of the form "SET Y = FUNC(B,W)" will give a value of Y corresponding to the value f(X) where X is the content of disc word W, block B and has a value between 0 and 1024.

Interpolation Between Functions

If a function of the form y = M f1(X) + N f2(X) is desired, where M and N change over the region of interest, two tables can be generated and stored in two blocks NB, NC, where f1(X) is in NB. Then use the command X SET(NB, NC) to place both tables in core buffers. Now the command SET Y = FUNC(B,W,K) will give a value of y where M = (3096-K)/3096 and N = K/3096. (3096 is the number of words in 24 129 word blocks)

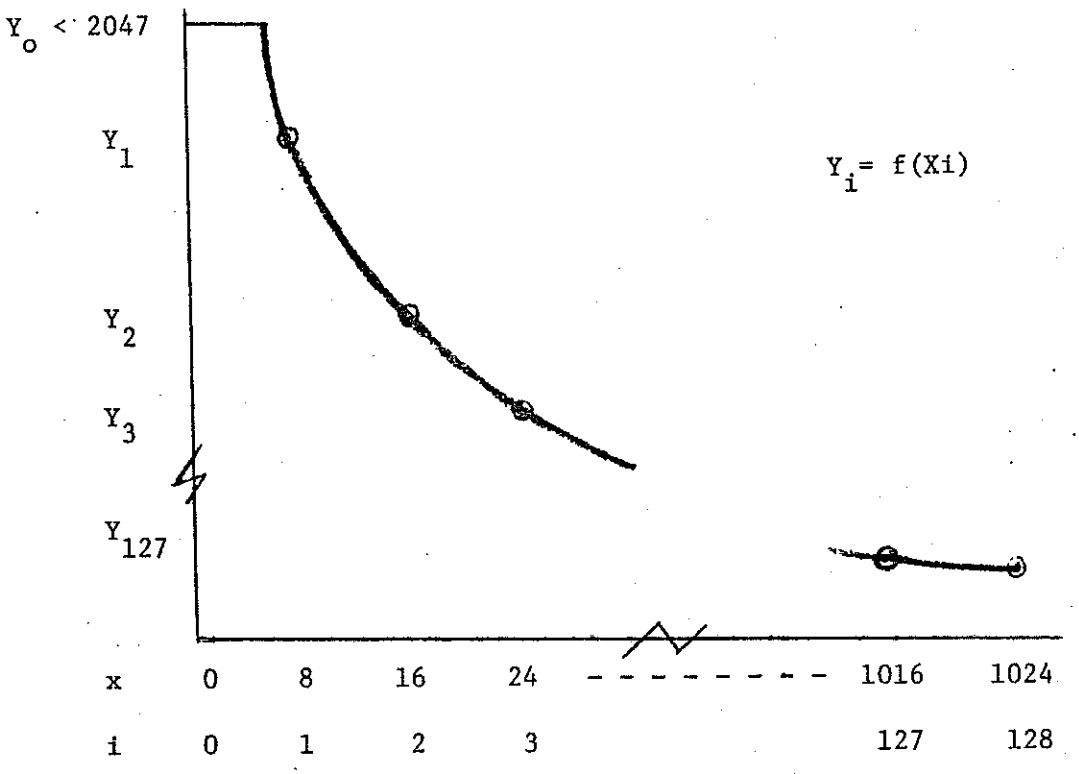
Caution

1. The "FUNC" command uses 2nd order ($Y = A+B\,X+ CX^2$) interpolation between points, so that the result for a rapidly varying function can be

less exact than may be desired.

2. The look-up tables are stored in Buffer "A" and "C" in the computer's memory. Buffer "A" is also used in the commands X ADD() X DN(), X UP(), X LFT(), X RIT() and X SUB(), thus if these commands are used, give the "X SET()" again before using "FUNC()".

N.B.: In X SET(A,C): A and C must be non-zero.



y_o is stored in the first word of the block

y_1 is stored in the second word

y_2 etc.

For the microphotometer, x corresponds to transmission and y corresponds to intensity.

```
Ø1.Ø1 C-DEMONSTRATION OF "FUNC" OPERATION.
Ø.1Ø5 FOR J=Ø,8,1Ø24;X PUT(5,J/8,1ØØ*FSQT(J))
Ø1.1Ø X SET(5)
Ø1.3Ø ASK !"X",XX
Ø1.4Ø X PUT(1,1,XX)
Ø1.5Ø TYPE "F(X)=",FUNC(1,1)
Ø1.6Ø GO 1.3
*
 GO

X:2 F(X)=     7Ø
X:102 F(X)=   1ØØ9
X:400 F(X)=   2ØØØ
X:900 F(X)=   2999
X:901 F(X)=   3ØØ1
```

APPENDIX G

Notes on Use of the PDP-8 CRT Display

The PDP-8 can store points and characters on the Tektronix type 611 memory oscilloscope. Several FOCAL instructions are available to control writing.

- X SWIT(-1) will erase the CRT.
- X DIS(A,B) will place a dot at the x,y coordinates A,B. Full scale is 1Ø23.
- X STAT(A,B,S) will direct future teletype output to the CRT, and set the x,y origin to A,B. Print scale is S. If A is negative, or an error diagnostic occurs, output reverts to the teletype.
- X PLOT(B,L,S,X,N,Ø,Ø,OF) will plot N blocks of 129 words from the disk starting at disk Block B with offset = OF. The Y deflection is proportional to S/L and full scale deflection for 1Ø23 counts is given with S = 16 and L = 1. L lines of 1Ø24 points will be plotted on successively higher segments of the display. X identical points will be plotted side by side for each word taken from the disk. The plotting origin X,Y is preset by X STAT(X,Y). Data values must be < 2Ø48 for correct treatment.

If L is zero, the chart recorder is used instead of the oscilloscope.

Example: 1.1 FOR J = Ø,1Ø23; X PUT(B,J,J); creating dummy data

1.3 X STAT(1,1); C-Set CRT baseline to bottom of CRT.

Then: 1.4 X PLOT(B,1,16,1,8) would draw a diagonal line across the display

Or: 1.4 X PLOT(B,1Ø,16,1Ø,8) would draw ten lines across the display, each one showing 1Ø3 words (1Ø23/1Ø) from the disk.

Special Features for CRT Text Writing

The text writing origin can always be reset while in the CRT character display mode by typing "C&". The use of & in any text string will also reset the origin, and special characters such as "bell" will produce a line feed.

-When text output reaches the bottom of the screen, a new column will start to the right of previously written text.

X STAT(-1) Sets output to teletype.

X STAT(0,0,S) returns output to CRT, but does not change the current character location. i.e. zero is ignored when setting the X, Y location for plotting or printing.

See Appendix J for use of Joystick and Curser on the CRT.

APPENDIX H

USE of the X PLOT( ) and X IFIX( ) Commands in FOCAL (Microphotometer only)

The function converter Set D = FUNC (see Appendix F) was designed especially to speed up the conversion of microphotometer transmission data to intensity values, when making strip chart records or CRT displays. In order to achieve higher plotting speeds, an additional command has been developed, which uses the function converter at the machine language level, so that several thousand points can be plotted with a single FOCAL command:

- X PLOT (B, L, S, X, N, ND, NF, OF) will automatically convert and plot up to 24 blocks of 129 data points interpolating between two conversion tables.

e.g.- with a conversion function fB in block NB corresponding to data in block 28, and a conversion function fC in block NC corresponding to data in block 50, data between these two limits, (say 11 blocks starting at block 33) could be plotted using linear combinations of the two functions, by the following commands:

```
X STAT(1,1); C- Baseline
X SET(NB, NC)
SET L = 0  ; C -output to chart recorder
X PLOT(33, L, S, X, 11, 50-28, 28, OF)
```

The conversion function used would be fB x K + fC x (1-K) where K has the value (33-28)/(50-28) for the first word and increases linearly to (33 + 10 + 128/129 -28)/(50-28) for the last word. The maximum allowed value of ND is 24. If more than 24 blocks are to be plotted, a conversion table should be measured or calculated at the end of each 24 block segment.

The meaning of variables L, S, X, OF is explained in Appendix G.

Conversion of Data on the Disk

The output from the PLOT(---) routine can be directed to the CRT or the strip chart recorder. It can also be redirected to the disk, thus rapidly converting the initial transmission data on the disk to digital intensity data. (This will be useful for computer aided analytical work) To store 24 blocks of disk transmission data back on the disk as intensity, instead of plotting, use:

```
X IFIX(B, 0,  16*SK, 1, 24,  24, B, OF)
```

instead of :

```
X PLOT(B, 0, 16*SK, X, 24, 24, B, OF)
```

Longer Plots with a Single Function

If a single conversion function is used, there is no limit (except the size of the disk) on the number of words that can be plotted.

```
X SET (NB, NB)
X STAT(1, 1)
X PLOT(B, L, S, X, N, ND, B, OF)
```

ND = N for use of conversion function

ND = Ø for direct output with no conversion.

APPENDIX I - ARCTAN

```
        W
C-LICK FOCAL AUG.9     KCJ(

01.01 C-ARCTAN ROUTINE:PROG 22.
01.02 C-ATAN(X)=X/(1+X*X)<1+M*2/3+(M↑2)*(2*4)/(3*5)
01.03 C  +(M↑3)*(2*4*6)/(3*5*7) + + +.....>
01.04 C WHERE M=X*X/(1+X*X)
01.10 S X1=FABS(X);S RV=0
01.14 IF (X1-1) 1.2,1.2;S X1=1/X1;S RV=-1
01.20 S M=X1*X1/(1+X1*X1)
01.30 S N=2;S D=3;S EX=1;S ML=2/3
01.40 S TL=1
01.50 F J=1,20;S TL=TL+M↑EX*ML;S N=N+2;S D=D+2;S EX=EX+1;S ML=ML*N/D
01.60 S AT=<X1/(1+X1*X1)>*TL
01.80 IF (RV) 1.82,1.9,1.9
01.82 S AT=1.570796327-AT
01.90 S AT=AT*FSGN(X)
01.99 R

02.01 T ! "                                    RADIANS          DEGREES        ERROR"
02.10 ASK !" DEG,TAN",JJ,X
02.20 DO 1
02.30 T %11.09 AT," ",AT*57.29577951," ",JJ-AT*57.29577951
02.40 G 2.1

31.98 W
31.99 X END(0)
*
```

The arc-tan subroutine has been removed from FOCAL to make room for longer dispatch tables. User's (hopefully few), who need to calculate an arctan can use the FOCAL language routine given here.

APPENDIX J

Joystick and Switch Panel

A FOCAL command can read the setting of any switch on the Program Control Panel. It can also display a movable non-storing fiducial mark on the 611 Memory Scope and turn on the 6 indicator lamps on the panel. The joystick is used to move the fiducial mark, and the final x, y co-ordinates of the mark can be returned to FOCAL by depressing a push button near the joystick.

SET D = FSWIT(GR, N, X, Y, M)

This command reads switch number N of Group GR, if x = y = 0.

- In group 1, switches are numbered 1, 4, 7, 10 and can have readings of 0, 1, ---, 7.
- In group 2, switches are numbered 1, 3, 5, 7, 9, 11 and can have readings 0, 1, 2, 3.
- In group 3, switches are numbered 1 through 11 and have readings of 1 or Ø.
- If M is non-zero, it is used as a mask to read several switches of one group simultaneously, with the reading of each switch number N multiplied by $2^{(N-1)}$.
- 6 indicator lights are provided, numbered 32, 16, 8, 4, 2, 1.
- X SWIT(0,8) : light lamp 8.
- X SWIT(0,5) : light lamps 4 and 1.
- X SWIT(-1) : erase memory scope

SET D = FSWIT(3, 11, X, Y, 0, Q)

A fiducial mark with initial co-ordinates X, Y is displayed on the CRT (full scale for X and Y is 1023). The mark can be moved by the joystick and when switch "3, 11" reads non-zero, the fiducial mark disappears and D holds

the final Y coordinate plus 1024 times the X co-ordinate. Normally the switch 3, 11 (the push button beside the joystick) is used, but any switch may be selected to terminate the fiducial display and return the final co-ordinates. Normally, to avoid double returns from a single switch motion, the program waits till switch 3, 11 reads Ø before displaying the marker. To get continuous returns with the switch held down, set Q = -1.

Example of Joystick Program

```
1.1  SET X = 400, SET Y = 400
1.2  SET D = FWIT(3,11,X,Y)
1.3  SET X = FITR(D/1024); SET Y = D-1024*X ; X STAT(X,Y)
1.4  T ! X,Y; GO 1.2 ; C~Prints X, Y values at location X, Y
```

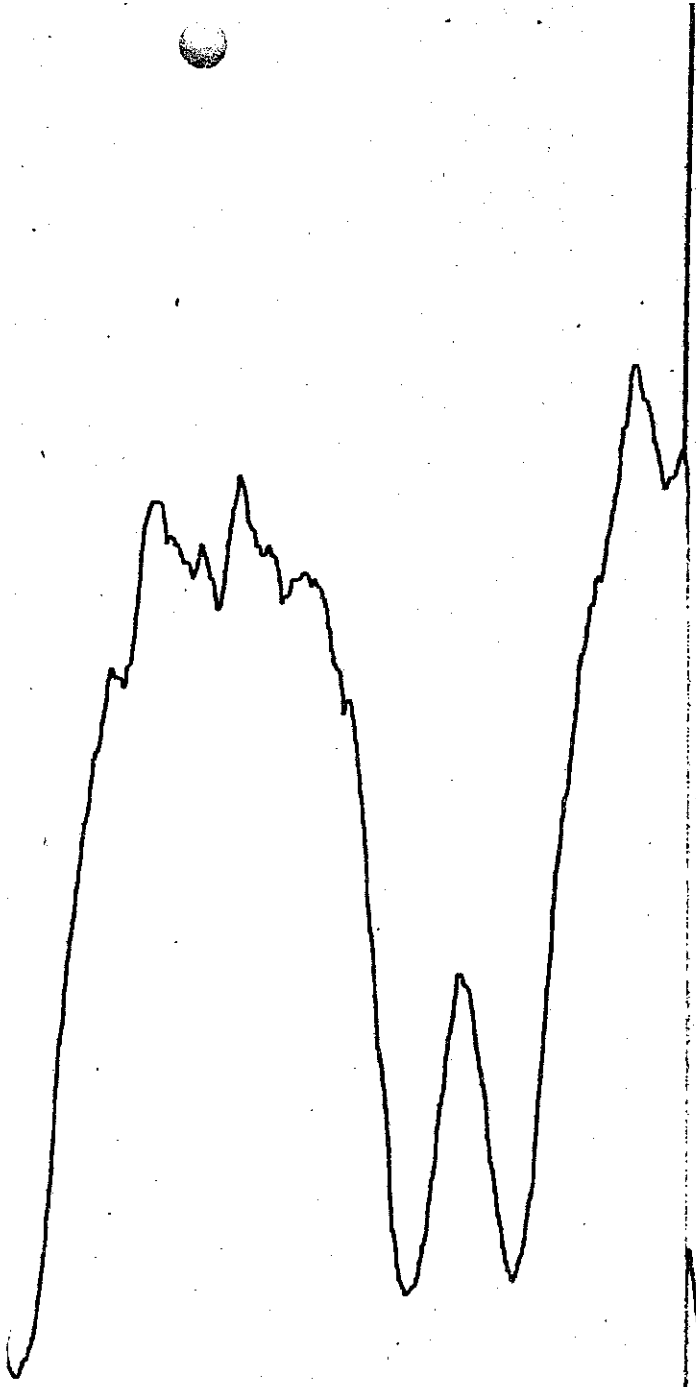
APPENDIX K

Plotter Speeds for the Microphotometer

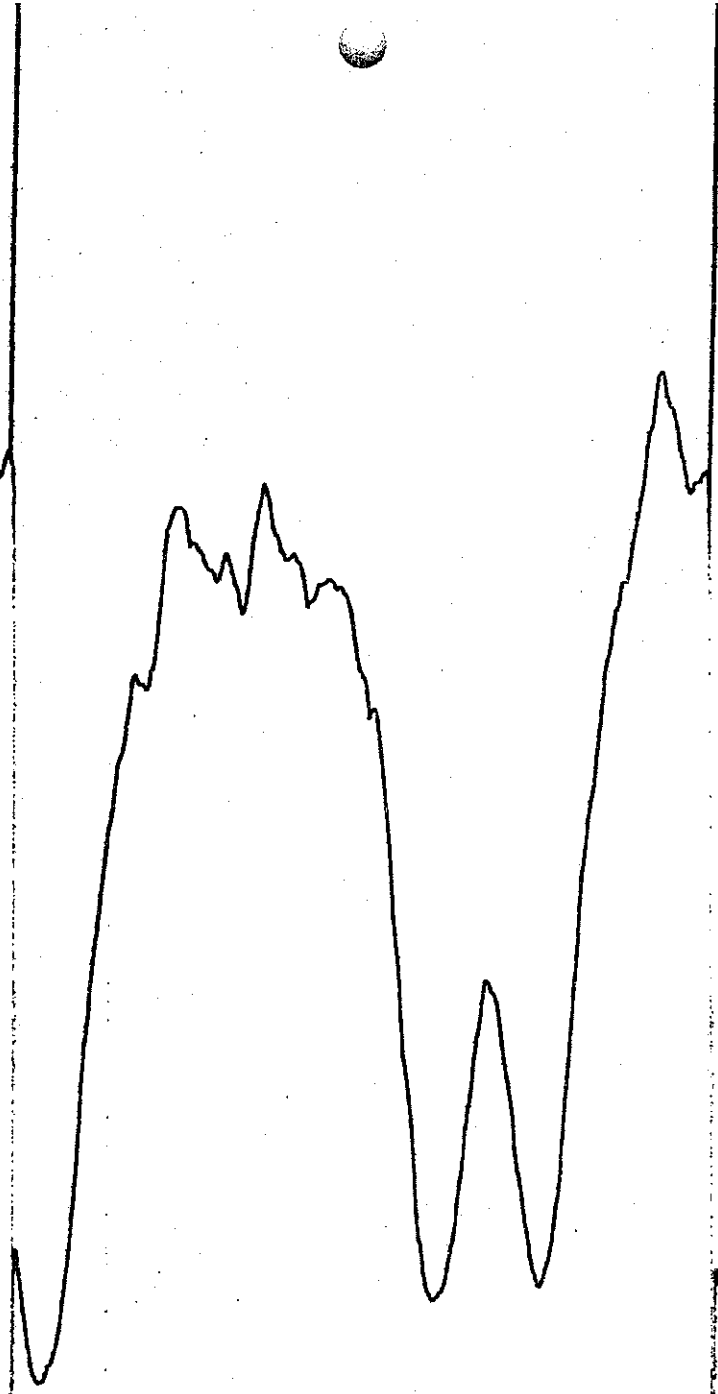
The microphotometer PDP-8 can drive the Houston plotter at speeds up to 0.5 inches/sec. If a restricted Xscale is used, some loss of fine detail can occur because the pen moves too slowly.

For maximum paper speeds, set the plotter buttons at 20"/min. In order to record more detail, set the plotter speed at 10"/min and request twice the dispersion, or at 5"/min and request four times the dispersion. The resulting chart scales will be the same but plotting time will double or quadruple, and detail of very sharp features will improve.

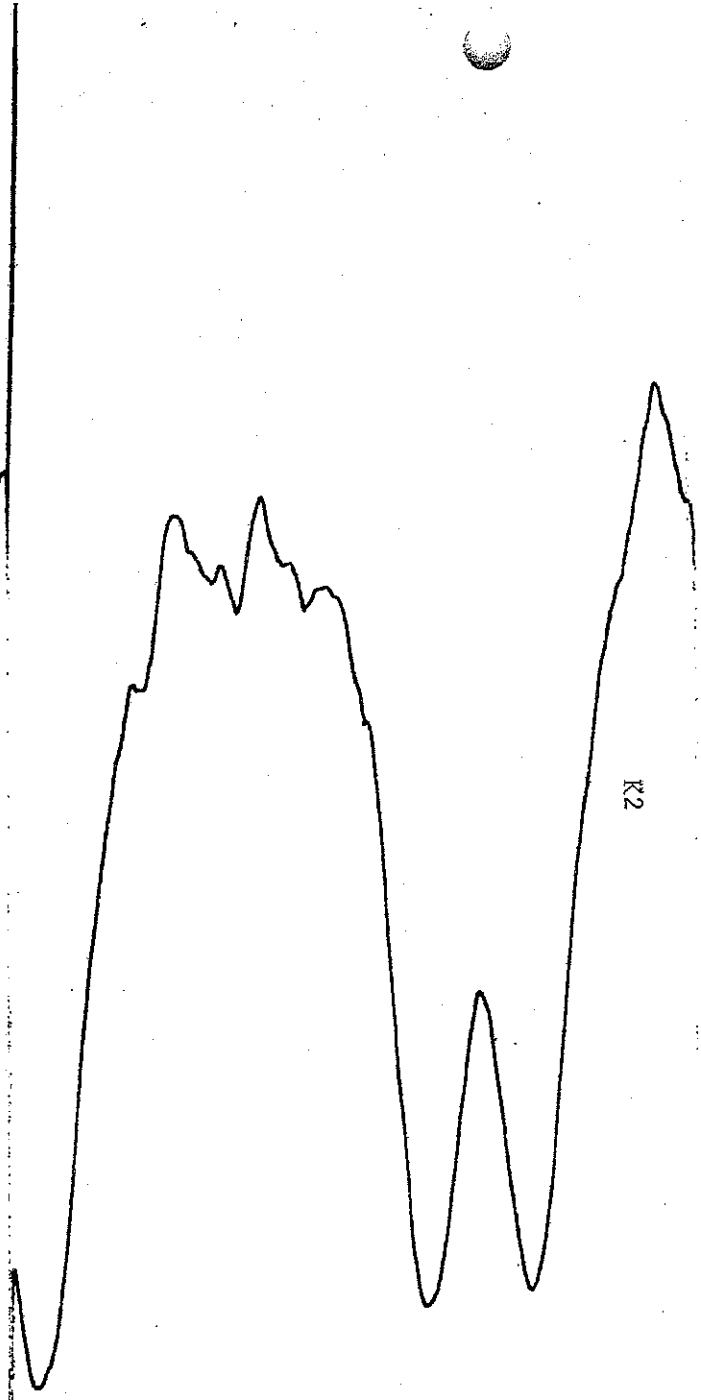
The attached records show the changes in detail that may be expected as chart speed is changed.



1/4 Speed

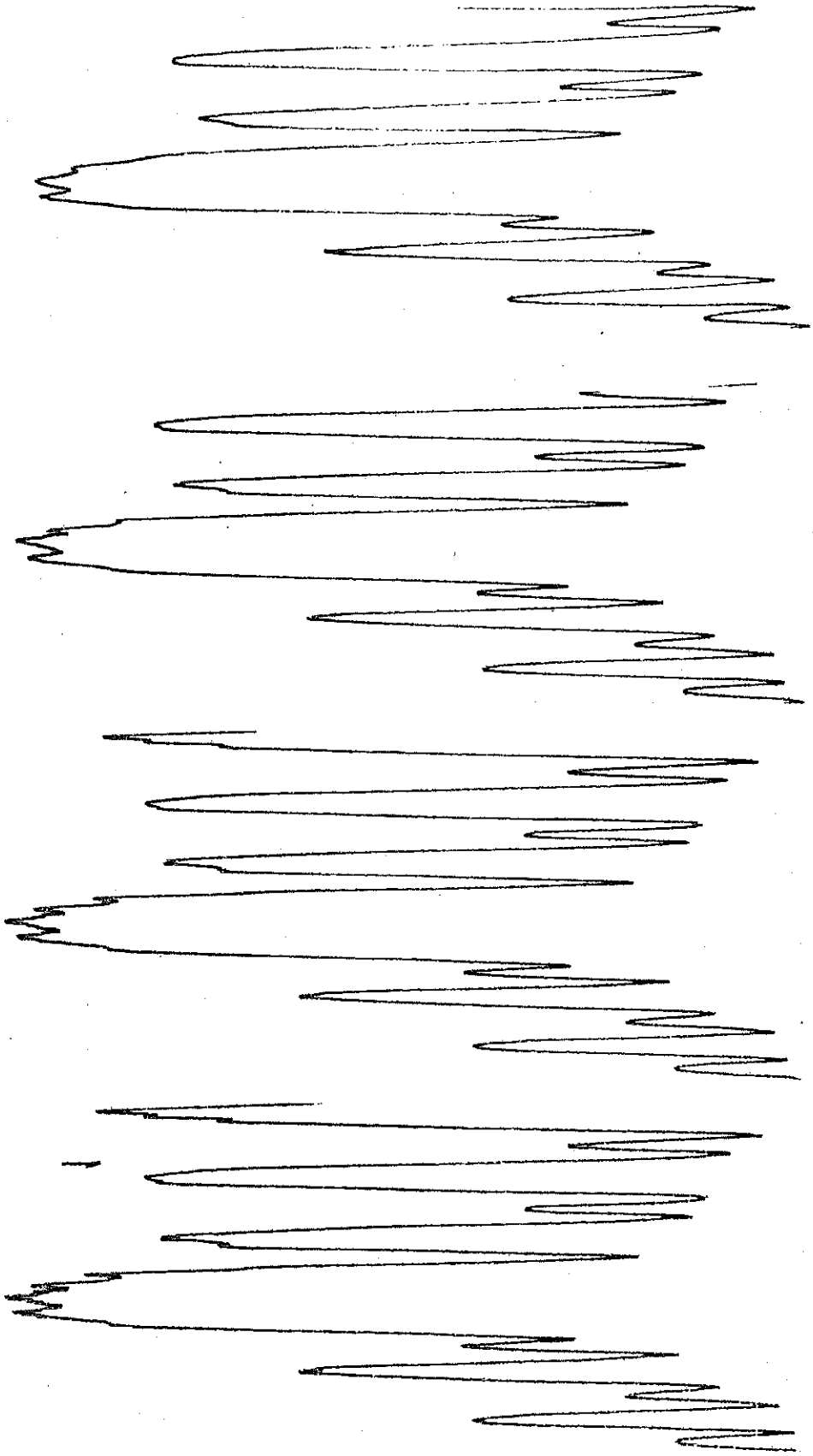


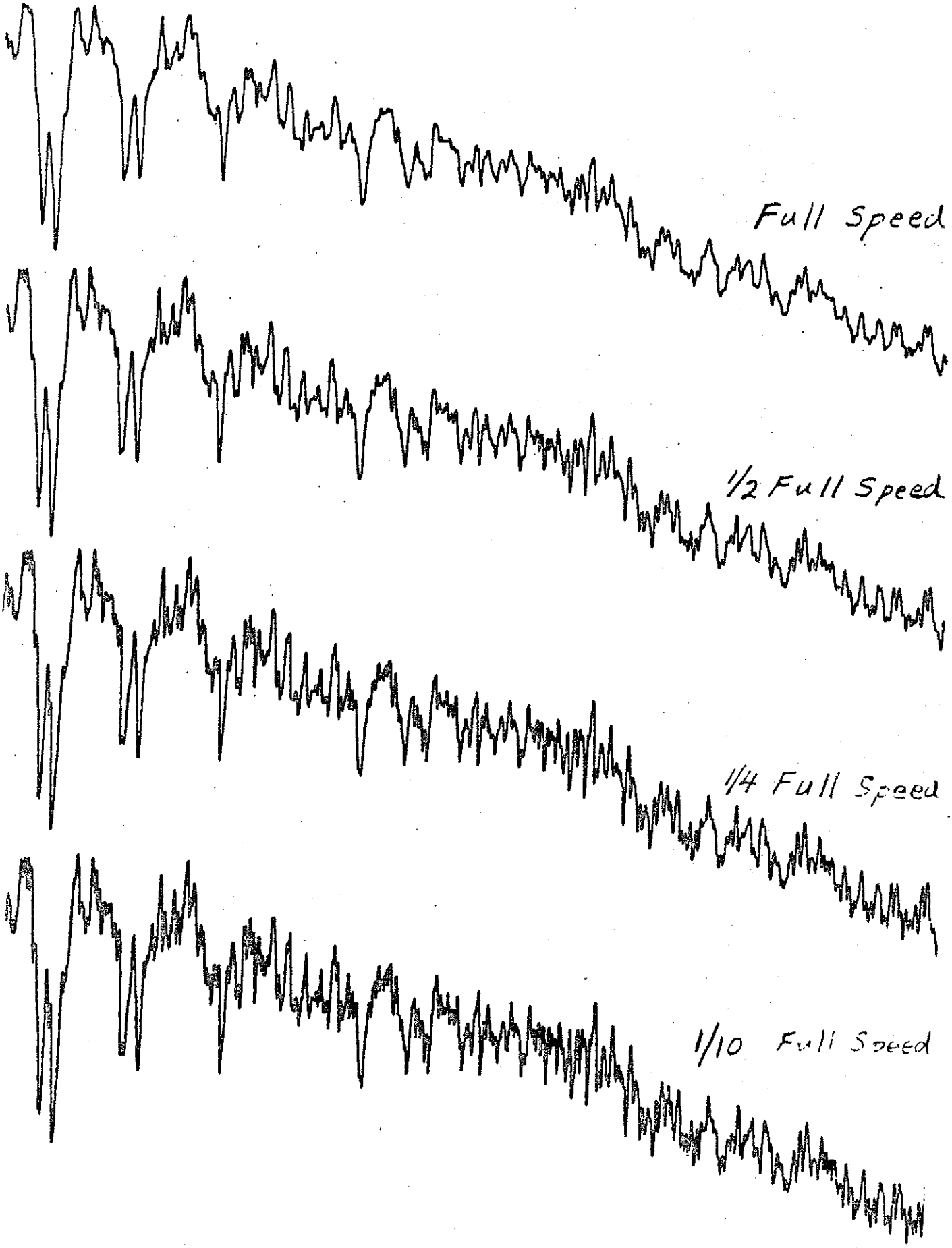
1/2 Speed



Full Speed

K2


Full Speed
1/2 Speed
1/4 Speed
1/16 Speed


Full Speed
1/2 Full Speed
1/4 Full Speed
1/10 Full Speed

```
ARG1    0050

        /CON0
        /A LIST OF CONSTANTS AND ADDRESSES
        FIELD 1
        KB1=140
        FNTABL=6234      /NEW FUNCTION LIST
        FNTABF=6346
        FNKB1=-6200+600+FNTABL+10
        FLETER=FNTABL+10
        LISTSM=600                  /FUNCTION LIST
        ARG1=50
        ARG2=ARG1+1
        ARG3=ARG2+1
        ARG4=ARG3+1
        ARG5=ARG4+1
        ARG6=ARG5+1
        ARG7=ARG6+1
        ARG8=ARG7+1
        ARG9=ARG8+1
        ARG10=ARG9+1     /(=61)
        ARG3H=10
        ARG4H=ARG3H+1
        ARG5H=ARG4H+1
        ARG6H=ARG5H+1
        ARG7H=ARG6H+1
        ARG8H=ARG7H+1
        ARG9H=ARG8H+1
        ARG10H=ARG9H+1
        /
        GETWRX=KB1+1
        /
        DXS=6057
        DXL=6053
        DIX=6054
        DYS=6067
        DYL=6063
        MUY=7405
        DVI=7407
        SHL=7413
        ASR=7415
        LSR=7417
        MQL=7421
        MQA=7501
        CCEC=6136
        CSCF=6133
        CCFF=6132
        /
        MVSTOP=6316
        XPOWER=6313      /STOP MICROPHOTOMETER CODES
        /
        /FOCAL CONSTANTS
```

```
                XRT2=12
                TELSW=16
                LASTV=31
                T1=32
                BOTTOM=35
                T2=71
                CFRS=133
                END=134
                ENDT=135
                EFUN3I=136
                CHAR=66
                COMBUF=132
                DAXIN=173
                ERROR2=4566
                GETC=4545
                PUSHJ=4540
                POPJ=5541
                EFUN=1743
                EVAL=1613
                INTEGER=53
                THISLN=23
                FINDLN=4555
                PC=22
                NAGSW=65
                PROC=611
                BUFR=60
                LINENO=67
                XRT=11
                AXOUT=17
                /
                F1=5354 /NEW DISPATCHER
                /
                LINE0=540
                LINE1=560
                LVARIB=3200
                SPRINT=2600
                BUFERB=7577
                /
                DISCX=20
                DTAPX=21
                MESAGX=22
                *0      /LOADER MISSES FIRST WORD
0000    0000    0
                *6
0006    5770    CLENGT,-2010
0007    0132    CLOKGO,KILALL
                *23
0023    0400    DDCORE,400      /INITIAL TEST VALUES
0024    7570    DDWCNT,7570
0025    0000    DISADD,0
0026    0010    DSFELD,0010
0027    0004    DTBLOK,4
0030    0000    DTUNIT,0
0031    0000    TEMPS0,0
0032    7577    M201,-201
0033    0000    BWTEST,0        /PARTIAL DISC BUFFER PROTECT
0034    3200    LASVAR,LVARIB   /HOLDS CURRENT LAST VARIABLE
0035    0044    FLACR,44        /FLAC
0036    5216    BUFEMD,-2562    /-BFTEMP-2010+3:TEXT END
0037    0020    P20,20
```

```
0040  7067  DISEND,-711      /700777 SHOULD BE LAST DISC ADDRESS
0041  0000  DTEST,0
0042  0000  PGLAST,0         /FOR CHAINING
0043  0500  FSDATA,500
0044  3000  FSPROG,3000      /LABL MUST SET THIS TO 160 OR FOCAL FAILS!
            /
            *76
0076  0100  P100,100
0077  7700  M100,-100
            DCSETX=112
            CLKCNT=113
            DISPAX=114       /ENTRY TO LFOC DISPATCH
            GETPRX=115
            BLOKIN=116
            INTESX=117
            PUTWRX=120
            LINPNT=121
            L0TPNT=122       /POINTS TO TEMP STORE FOR LINE0
            FLAGX=123
            MVBUFX=124
            WAITX=125
            *126
0126  0000  INTRUP,0
            TYPEX=127
            CRLFX=130        EXITX — JUNE /73 ?!
            KILALL=132
            FLSETX=133
            NOWNAM=134
            PGRETN=135       /ALSO FOR CHAINING
            OCTPNX=136       /USED TO PRINT CHAIN ADDRESS.
            BWRITX=137
```

```
/
/
/MCON
XLIST
/
CSCF=6133
CCEC=6136
ADCV=6532
ADSF=6531
ADRB=6534
MVLEFT=6314
MVRIHT=6315
STEPUP=6311
STEPDN=6312
PLSTEP=6317
REDBUF=6353
ERASE=6362
LODBF1=6351
/
BUFERA=5577
BUFERC=5100
/
XBASE=62
YBASE=63
XLOC=64
YLOC=65
LISMVX=66
LSBEGX=67
LSCLRX=70
DREADX=71
PUTLSX=72
SCALE=73
XMAX=74 /NOTE DIFFERENT FROM XCON
/
CRTGOL=6370      /SEE FOC4
LISLET=6044      /LETTERING LIST
TELSW=16
OUTDEV=63
XOUTL=2676
XLIST
PAUSE

*
```

```
                    /XCON
                    FIELD 1
                    /
                    *45
0045    4000        BUFRDX,4000
0046    1000        P1000,1000
0047    6000        M2000,-2000
                    /
                    *62
0062    0000        XBASE,0
0063    0000        YBASE,0
0064    0000        XLOC,0
0065    0000        YLOC,0
0066    0000        SCALE,0
0067    0000        LOTEMP,0
0070    0000        HITEMP,0
0071    0000        SIGN,0
0072    0000        XMAX,0
0073    0040        P40,40
0074    7740        M40,-40
                    NORMAL=75
                    /
                    COMLOC=106          /CALCOMP LOCATION
                    RBUFR0=107
                    RBUFR1=110          /FOR EDIR
                    BUFSTX=111
                    DCSETX=112
                    /
                    LISLET=6044         /CRT LETTER LIST
                    CRTGOL=6370
                    TELSW=16
                    OUTDEV=63
                    XOUTL=2676
                    /
                    ERASE=6362
                    LODBF1=6351
                    REDBUF=6353
                    PLSTEP=6317
                    SYNSKP=6452
                    PROSKP=6461
                    DATSKP=6451
                    CONSKP=6462
                    MCSTEP=6454
                    MSTOP=6456
                    SCOUNT=6455
                    READLO=6464
                    READHI=6465
                    FUNLOD=6453
                    TIMEHI=6467
                    TIMELO=6457
```

```
.PALP
*OUT-S:LABL
*
*IN-S:CON0,S:LABL
*
*
*OPT-T

ARG1    0050

                /CON0
                XLIST
                PAUSE/
                /LABL
                FIELD 1
                *550
0550    4015    4015    / M
0551    1103    1103    /IC
0552    6762    6762    /72
0553    5510    5510    /-H
                /
                *DISEND
0040    7067    -711    /END OF DISC DATA AREA
                *FSPROG
0044    0500    500     /FIRST DATA BLOCK
                *FSPROG
0044    0160    160     /FIRST PROG. BLOCK
                /
                /LOAD OVER MFOC TO LABEL EACH NEW VERSION.
                /MUST BE LOADED AFTER ALL ELSE. OTHERWISE X CALL FAILS!
```

Core Usage - Lick FOCAL - 1973

Field 1

0 - 5 LFOC

6 - 7 CONØ
10-17 ARGH, Temp

20-44 CONØ
76-77 CONØ

112-130 CONØ
132-137 CONØ

240-376 LFOC
400-461 LFOC

462-537 Tely Buffer

540-554 LFOC-LINEØ
555-556 LFOC-CHAIN
560-- TEXT
*600-744 FOC4(FNKBN)

*746-767 FOC4 (FNTABF)

*1000-1173 GODO
*1200-1577 COPE
*1600-1753 COPG
*2000-2362 FAST
*2400-2540 COPG
6000-6041 ENTR

7000-7145 GWRD
7150-7177 Chain Nest Buffer
7200-7271 DISK 1OUT
7274-7320-MESG
7322-7377 FLAG 1OUT
7400-7422 DSET
7425-7434 CRT entry
7435-7440 INTEX
7447-7576 DECT 1OUT

Field Ø

2414-- 2424. Apparently empty
7515-7557 Empty

31 LFOC
132 LFOC
134 LFOC
173 LFOC

375-407 EXEC

1012 EXEC

1142-1157 LFOC
1201 EXEC
1335-1336 FOC4
1343-1353 LFOC
1553-1561 GOTØ

2600-2655 INTEX
2662-2743

3120-3136----- CHAIN
3140-3177 TTY Output Buffer
*4600-4616 LFOC
4726-4727 LFOC
4732-4765 FOC5
5000-5032 FOC5

5333 LFOC
5354-5376 LFOC
6002 LFOC
6200-6233 FOC5
6234-6367 FOC4 (loads from 10600--)
7503-7514 LFOC

7560-7564 - 8K overlay
7572-7577 - 8K overlay

*Initializing only

Microphotometer Core Allocation - Nov/72 - Field 1

0-5 FOCAL 6-7 CONØ 20-44 CONØ 76-77 CONØ 50-61 ARG 62-73 MCON 76-77 CONØ 112-130 CONØ 132-137 CONØ 140-237 KB1	1000-1177 GODO 560-2567 TEXT 5000-5077 PUTL 5100-5300 BUFERC 5400-5567 CONV 5577-5777 BUFERA XTRA! 15000-5577; 6000-6041 ENTR Load LABL after all else!
① 6042-6154 DATU 6200-6310 DATU 6400-6533 STAG 6545-6577 MINM 6600-6661 MULT 6676-6777 DIUM	④ 6044-6064 PUTN 6066-6110 FSET 6200-6354 PLAT 6400-6573 PLAT
② 6044-6112 SHOW 6113-6144 GOTO 6267-6377 COMP 6422-6527 6531-6577 SWIT (Tape 12M) 6600-6772	⑤ 6112-6146 SHIF 6200-6377 NAME 6520-6576 ADER 6600-6775 CHAIN
③ 6044-6343 LIST 6400-6542 CRT 6545-6576 SAV4 6600-6765 (CRT) 6770-6777 (SAV4)	⑥ (Use FNKB1+66--77 for routines in program 6) 6550-6772 TAPE (From Tape 12M-3)

Start at 12000 to create a 'FAST' tape.

.FAST
.XTRA
.SET1
.TAPE
.MFOC
.STEN

Scanner System Map (Field 1) Nov. 3/72

6-~~10~~-- 44 CONØ 10-17 Temporary STORE 45-47 XCON 50-61 ARG1--ARG10 62-66 XCON 67- LOTEMP } Temp 70- HITEMP } Store 71- SIGN } 72-75 XCON 76-77 CONØ 100-102 Temp (DIVD) ~~103-105 ??~~ 106-112 XCON 114-237 CONO,KB1 Table	6000-6041 ENTR 1000-1177 GODO ~~1200-2046 ??????~~ 2000-2355 } FAST 2400-2526 } 226-237 } Zeroed in 732-744 } PREP 1000-1577 TOVR 2000 - 3777 Buffer 1 4000 - 5777 Buffer Ø
6042-6120 TOTL ① 6135-6173 EDIT 6200-6374 EDIT 6400-6515 PEAK - Uses EDIT 6520-6544 COMP — 6545-6577 STAP 6600-6666 ADSC 6670-6762 (COMP) 6765-6177 CLER	6043-6075 SHIF ④ — DIS 6200-6231 GOTO* — 6304-6325 PUTN ~~6326-6352 PLOT~~ — ~~6400-6562 (PLOT)~~ — 6600-6774 CHAIN*
6044-6343 LIST ② — 6400-6542 CRT* 6545-6576 SAV4 6600-6765 (CRT) 6770-6777 (SAV4) 7425-7434 Permanent CRT 10770-776 ⇒ 6170-6176	6044-6144 FDRM ⑤ 6145-6164 LOOK — 6200-6377 NAME 6400-6567 NCRT 6570-6576 ZCOM 6600-6721 (NCRT) 6722-6765 (LOOK) 6771-6777 PAUS
6200-6376 } 6042-6167 } DIVD, MOVF 6400-6421 } 6422-6527 } 6531-6577 } SWIT 6600-6772 } ③	6134-6177 ~~REOR~~ REVR ⑥ 6200-6370 } 6400-6507 } MEMF 6550-6772 TAPE! N.B.-KB1+66 FF. for Prog. 6

—Always load LABL last or XFOC is wrong!

*Uses Field Ø parts.

APPENDIX M

Disk Overlay System

Modifications to FOCAL allow for up to 64 special instructions of the form "X Code(ARG3,--ARG10)." Each such instruction can call a specially written machine language program to perform some required function.

The core memory space in the PDP 8I is limited, and when used with the scanner, 25% of the memory is required for data storage. After essential system functions such as disk and Dectape access are provided, only 512 words remain for machine language routines, and 800 words for FOCAL text.

The text area has been expanded by use of chaining and automatic subroutine calling from Dectape.

The machine language area has been expanded by an overlay system using the DF 32 Disk.

Overlay System

Machine language programs are assembled, and then stored on the Dectape in a table called "SET1". SET1 is placed on the last 3.5 K words of the disk before starting to work. (by the bootstrap routine)

A table in FOCAL gives the location on the disk of each machine language program, and when one is requested by a FOCAL command, it is transferred from the disk into core memory, before running.

Generally, this overlay procedure does not cost much in execution time, but certain sequences may be unexpectedly slow: For example, the command SET D = FCHAN(N) uses overlay No. 1, while the CRT lettering routine uses overlay No. 2. Thus a sequence:

1.1 X STAT(1,1000,1); For J = 0,499; T! FCHAN(J) would have to get two programs from the disk for each channel printed on the CRT, which would limit the printing speed. Higher speed would be obtained by:

```
1.1 X STAT(1,1000,1); For J = 0,50,450;DO 2
1.2 Quit
2.1 For K = 0,49; SET D(K) = FCHAN(J+K)

2.2 For K = 0,49; T! D(K)
```

since the disk would only be used 20 times instead of 1000 times.

PROGRAM STORAGE ALLOCATIONS - Scanner System

Permanent	FPUT, FTAK,
Overlay 1	FTOTL, EDIT, SAV, PULL, CHAN, SHFT, MSAV, MGET, CLER, IN, OUT. ERAS, COMP, CPEN, FPEAK
Overlay 2	STAT, CRT Lettering, STOR, FASK
Overlay 3	DIVD, MOVE, SWIT
Overlay 4	PUTN, PLOT, ICRT, DIS, PEN, FILE, CALL, END, SHFT, GO,
Overlay 5	X CRT(), FORM, LOOK, NAME, ZCOM, PAUS
Overlay 6	- Scanner memory control

The overlay system commandeers the last 3.5 K words of the disk, so programs attempting to access beyond Block 225 or Record 27 will cause a diagnostic "DISK END".

PROGRAMMER'S NOTE - DISK OVERLAY

The Disk Overlay System loads one of several machine language programs into field 1 core locations 6042-6777 when a FOCAL command requires a program not already in core. Dispatch table entries less than 240 are recognized as program numbers and the referenced program is read from the disk. (Whenever a program is in core, the corresponding Dispatch table location holds an address greater than 2000.

System Building

A. Initialize: Call "FOCAL", load "GODO", load "ENTR", Call INIT;

("FOCAL" is the Field 1 part of Lick FOCAL)

SAVE SET1 ! 500-6777; (saves entries to permanent programs in "FOCAL")

SAVE XFOC! 10000-1177, 6000, 7000-7577; 1000

B. To add a new program (machine language) to XFOC, using the Disk Monitor:

Call XFOC

Load all programs for one overlay image

Load LABL

Call SET1

Call STOR

STOR first removes all previous references to the new overlay program number. Then, for each new entry (to programs between 6042 and 6777) found in the XFOC dispatch table, it places a reference to the program number in corresponding words of the dispatch table images in"SET1". Then it copies the new entries into the single dispatch table image in "SET1" that corresponds to the new program number. The new entries in the "XFOC" dispatch table are replaced by references to the new program number.

Finally the new program is copied from locations 6042-6777 to the SET1 image corresponding to the new program's number.

In case a new program uses a dispatch table location already taken by a program of different number, a diagnostic will be typed giving the location in "SET1" that is to be changed, as well as the new and old contents.

When done, "STOR" requests that the newly revised version of "SET1" and "XFOC" be saved. The updated disk image is saved by "PUTT".

Finally, "PIP" is used to ~~transfer~~ Copy the new ~~"SET1" and~~ "XFOC" to the Master system tape. When used in a FOCAL system, "SET1" is loaded onto the disk by "XFOC" , only if the tape monitor is in core.

For general use, "FAST" tapes are prepared containing the FOCAL system It is advisable to run FOCAL from a "FAST" tape to avoid the possibility of a FOCAL command overwriting part of a source tape.

Programmer's Note

Procedure to Prepare and Add Machine Language Subroutines

to LICK FOCAL (Scanner Version)

A) Without DISK overlay. (Only Basic FOCAL commands plus PUT, FTAK will be available.

- Program can use Field 1 locations 2000-6777 as well as 10,---17, 100-110. Note however that normally, data buffers occupy 2000-5777
- Select name code and entry point for new routine.

  The command for such a program would be:

  Set D = FABCD(ARG3, ARG4,---ARG10) or X AECD( ) ARG3, ARG4, ---ARG10)

Proceed the Coding for your Program by:

```
*KB1+N     N=12---77 65 77
BEGN

*FNKB1+N
CODE FOR "ABCD"  see Note I

*GETPRX
BEGØ              (DISCONNECTS THE OVERLAY SYSTEM)

*6ØØØ
BEGØ,Ø
   CDF!CIF        (KILLS ANY ILLEGAL OVERLAY ATTEMPT)
   JMP I .+1
   2ØØ  (RESTART FOCAL)

BEGN,Ø
-
-
-
YOUR PROGRAM

-
-
TAD RESUL1        /LOW ORDER 12 BITS OF RESULT
DCA ARG2
TAD RESUL2        /HIGH ORDER 11 BITS AND SIGN
DCA ARG1
JMP I BEGN
$
```

When assembling the program, use PALP

```
OUT:  S:ABCD
 IN:  S:CONØ, S:ABCD
```

CONØ contains pointers to page Ø, field 1: ARG1,---ARG10, KB1, FNKB1, etc., as well as entries to teletype, DISC and DECtape handlers. Several numerical constants are also defined.

To add the finished program to FOCAL DECtape, first load:

FOCAL (XFOC) then load, "ABCD"

SAVE NFOC! 10000-1177, 2000-7577; 1000

NFOC now includes your special program.

To start the program: .NFOC (Ignore the message typed here)
.STEN

B. WITH DISC OVERLAY SYSTEM: (recommended)

ASSEMBLE THE PROGRAM AS BEFORE, BUT PRECEDE THE PROGRAM BY:

```
*KB1+N              N =12--  65.
BEGN

*FNKB1+N
XXXX                OCTAL NUMBER REPRESENTING COMMAND CODE (See Note I)

*6Ø42
-BEGN, 0
-
YOUR MACHINE LANGUAGE PROGRAM HERE
-
- JUMP I BEGN
$
```

WHEN LOADING INTO THE FOCAL SYSTEM:

```
.XFOC
.LOAD
IN:S:"ABCD'  (LOAD YOUR MACHINE LANGUAGE PROGRAM), S:LABL*

.SET1*
.STOR
PROGRAM NØ:  Choose a program No. whose current contents are not needed.

SAVE SET1 -----ETC.
.SAVE SET1! 500-6777;
.SAVE XFOC! 1ØØØØ-1177,6ØØØ-7577;1ØØØ
```

NOW USE "PIP" TO TRANSFER PROGRAM XFOC AND SET1 TO DECTAPE. See Page 148

*LABL must always be loaded just before SAVE XFOC, otherwise chaining and data storage pointers will be incorrect.

NOTES:

I. A "hash" code technique is used to allow FOCAL to recognize function names. ASCII codes for each successive character are added, with successive shifts of one octal digit. Only the lower 11 bits are retained.

For example, the code for "NAME" would be the sum of ASCII codes for N A M E.

$$[N*(1000)_8 + A*(100)_8 + M*(10)_8 + E]$$

The lower 11 bits form a numerical code for the name. The code for "NAME" would be $(1555)_8$. Any one-to-four letter code can be used for a command code. Since only 2047 codes are possible to cover $(26)^4$ possible names, care should be taken to avoid duplicate codes.

FOCAL matches the position of the code in one list starting at FNKB1, with the position of an entry point to the desired subroutine in a second list starting at KB1.

II. The ASC11 language source programs for the Lick Focal system are stored as individual short listings using the standard DF 32 Disc Monitor.

The image of the disc is saved on a Dectape, and is loaded back onto the disc in order to add or change instructions in Lick Focal.

See next page

TO ~~START the prog~~ build the new system

- FAST (bootstrap coding)
- SET1 (Disc Overlays)
- XTRA (any core resident code 3000--5777)
- TAPE (use tape monitor now)
- XFOC (or MFOC or GFOC) - Field 1 part - loads SET1 to DISC
- STEN Field 0 part loads FNKB1 table to Field 0 - 6200 - 6377.

* FOCAL IS in core and running

To save the new system on a new tape. (timing tracks written), mount new tape as tape 8. (write enabled) and start the computer manually at Field 1, Loc 2000. Tape will spin and copy whole system. Types "DONE" when finished.

Building a "FAST" Focal System.

user responses are underlined

```
.XFOC
.LOAD
*IN-S:REVR,S:MEMF,S:TAPE
*
*
*
ST=  ↵
↑↑↑↑
.SET1
.STOP
PROG NO.(1--6):6

.SAVE SET1!500-7177;
...XFOC!10000-1177,6000,7000-7577;1000
.SAVE SET1!500-6777;
.LOAD
*IN-S:LABL
*
ST= ↵
↑↑
.SAVE XFOC!10000-1177,6000,7000-7577;1000
.
.PUTT
SET TAPE 8 TO WRITE ENABLED.                    (Save updated Disk Image)
FILE NO.(0-4):2
 FILE 2 FULL.TYPE Y TO REUSE IT :Y
DONE!
.PIP
*OPT-S

*OUT-D0:XFOC
*
*IN-S:XFOC
*↑
*OPT-S

*OUT-D0:SET1
*
*IN-S:SET1
*↑
*OPT-        CTRL-C
.SET1        [.XTRA - if core resident code needed in the area 12000-15777!]
.FAST
.TAPE
.XFOC
.STEN
*W
C:LICK FOCAL SCN72-N  E@@@      MOUNT A New Tape,
*                               START at 12000.
DONE!
*
```

New FOCAL system is now stored on the new tape.

ADDING INSTRUCTIONS TO FOCAL (Using X NAME( ))

Introduction

Specially written instructions for Lick FOCAL are usually stored on a protected area of the DISK memory, as 6 individual sets which are automatically called into core memory when their specific FOCAL command is used. A special book-keeping program is now available which allows users to add many more special instructions to the system with no danger of damage to those already provided. The book-keeping programs "PREP" and "TOVR" store additional instruction sets on the program DEC-TAPE. A FOCAL instruction X NAME(N) takes instruction set N from the program DECTAPE and stores it on the DISK, after which instructions from Set N can be used just like any other FOCAL instruction. The instruction sets can be switched as many times as desired - by repeated use of X NAME(-).

Storing the New Instructions on a Program Tape

Use the DISK MONITOR system to prepare machine language subroutines for core memory, field 1, location 6044-6777 (see below). Pointers to the subroutines are located in locations KB1 + 66 to KB1 + 77. The codes for the corresponding FOCAL commands go into locations FNKB1 + 66 to FNKB1 + 77. Currently, (May 2, 1972) KB1 = 140, FNKB1 = 744. (All addresses are in octal numbers)

The DISK MONITOR types "." when ready to accept commands:

> TYPE 'PREP', press RETURN, load your subroutines plus their entry names and pointers into core, then type 'TOVR' and press RETURN. The program will request an overlay program number and an identification (up to 30 characters). When these requests are answered, it will store the new subroutine on a FOCAL Program Tape, mounted on UNIT #7.

Using the Additional Instructions

To type out identifications for N + 1 overlay subroutines on a program tape, use the FOCAL command X WHAT(N). To enable all the instructions stored in overlay N, use instruction X NAME(N). This reads the subroutine from DECTAPE #8 and stores it on the DISK as overlay No. 6. [The current contents of core buffer Ø of the scanner system are lost, and the instructions previously stored on DISK overlay No. 6 are temporarily disabled.] To re-enable the original instructions of overlay No. 6, type X NAME(Ø). To lock the system against further uses of X NAME(N), type X WHAT(-1).

Preparing an Additional Instruction Set

The PDP 8I DISK MONITOR includes a machine language assembler and text editor which may be used to prepare machine language programs using symbolic codes. The language and procedure are described at various levels of detail in a number of booklets stored near the PDP 8*. A sample program is included with this description. Note especially that the system subroutines which read and write DISK and DECTAPE and which output data to the TELETYPE can be easily accessed by user generated programs. (See Appendix D.)

The entries to new instructions, and the handling of input and output arguments require special explanation:

> Two tables are used by FOCAL to identify and start a subroutine corresponding to a command X "ABC"(--). The first table is located at FNKB1 + 66 to FNKB1 + 77 inclusive and contains a code corresponding to the command "ABC". The code is generated by successively shifting the ASCII codes for the letters in the command by one octal digit and summing. The code for ABC would be 30100 + 3020 + 303 (octal). We keep only the low 11 bits of the result. Thus the code for ABC is 3423.

---

*See Programming Languages (2), page 13-3; and Introduction to Programming 8-24, 8-21. [Most users will require an hour's tutorial session before being able to use this information]

Caution: The same numerical codes can be produced by more than one command word. Commands that have a code appearing on the attached list will not work, because FOCAL will always select the wrong subroutine.

The second table is located at KB1 + 66 to KB1 + 77. It contains pointers to the subroutines that are to be started.

The arguments are named ARG1, ARG 2,--ARG10 in the command X ABC(ARG3, ARG4--). The resultant of a subroutine may be put in ARG1 (upper 12 bits) and ARG2 (lower 12 bits). Instructions such as Set D = FABC(---) put D equal to whatever the subroutine ABC leaves in ARG1 and ARG2.

The upper 12 bits of any argument will be found in location ARG3H ARG4H etc. Since these locations are also used as auto index registers, care must be taken to retrieve the register content before using the register for other purposes. Any of the arguments locations may be used as temporary storage registers at the programmer's discretion.

Program Assembling

A list of constants and pointers provides addresses for the argument table and the name and dispatch tables, as well as pointers needed for reading or writing of DISK and DECTAPE. The list is titled CONØ and is usually assembled in front of any new subroutine, to give the assembler "PALP" the necessary information. (See Appendix L.)

In order to prepare machine language subroutines for FOCAL, obtain a copy of TAPE #13 - "USER'S SOURCE TAPE MASTER". This tape includes PREP, TOVR, CONØ, along with a binary program loader, DISC and DECTAPE monitors, and the symbolic editing and assembler programs EDIT and PALP.

Bootstrap the tape, type GETT to load the DISK MONITOR. To use the DISK MONITOR, type DISK. After editing or assembling programs on the DISK, type PUTT to save the DISK contents on your Dectape.

```
.PALP
*OUT-S:DEMO
*
*IN-S:CON0,S:DEMO
*
*
*OPT-T

ARG1    0050

                /CON0
                XLIST
                PAUSE/
                /
                /DEMO
                /DEMONSTRATION OF X NAME( )  OVERLAY PREPARATION.
                /
                *INKB1+66
0732    0131    131-      /DEM1
0733    0132    132       /DEM2
                /
                *KB1+66
0226    6042    DEMON1
0227    6052    DEMON2
                /
                *6042
6042    0000    DEMON1,0
6043    1052      TAD ARG3
6044    7425      MQL!MUY
6045    0100      100
6046    3050      DCA ARG1
6047    7501      MQA
6050    3051      DCA ARG2,       /SAVE RESULT FOR FOCAL
6051    5642      JMP I DEMON1
                /
6052    0000    DEMON2,0
6053    4422      JMS I MESAGX  /"THIS IS A DEMONSTRATION"
6054    2410    TEXT /TH
6055    1123    IS                    TEXT /THIS IS ---- /
6056    4011     I
6057    2340    S
6060    0140    A
6061    0405    DE
6062    1517    MO
6063    1623    NS
6064    2422    TR
6065    0124    AT
6066    1117    IO
6067    1656    N.
6070    0000    /
6071    5652      JMP I DEMON2

.
```

OPERATION SEQUENCE FOR PROGRAM STORAGE*

·GETT
SET TAPE 8 TO WRITE LOCK.
FILE NO.(Ø-4):3

·DISC

·TOVR

YOU SHOULD TYPE 'PREP' FIRST OF ALL!
·PREP (Error Printouts)
·TOVR

THERE ARE NO ENTRIES TO YOUR PROGRAM!

(PRESSED CTRL-C)

·PREP
·LOAD
*IN-S:~~ETAD~~ DEMO (A previously assembled program.)
*
ST=
↑↑ - - -(Press CTRL-P)
·TOVR

SAVE (ON TAPE 7) AS OVERLAY NO.:1
TYPE I.D;PRESS RETURN: ~~TAPE EDITING MAY 19/72.~~ DEMONSTRATION

OVERLAY STORED!

(CHANGE FOCAL USER TAPE FROM #7 TO #8
BOOTSTRAP IT.)

*X WHAT ~~1,6~~ (1,6)

1:
~~TAPE EDITING MAY19/72.~~ DEMONSTRATION
2:

3:

4: X DEM2(0)

5: THIS IS A DEMONSTRATION.

6:

7:*

*Operator typing is underlined.

X NAME(1)
SET D = FDEM1(10) ; T !"D=", %5D ; X DEM2(0)
D = 640THIS IS A DEMONSTRATION

CODES FOR FUNCTIONS AND "X" COMMANDS

LICK FOCAL DEC/72

CODE	COMMAND	CODE	COMMAND	CODE	COMMAND
13	COS	1200	MEMX	2465	MOVE
33	DIS	1201	MEMY	2533	ERAS
44	CRT	1216	MOV	2545	FILE
164	END	1240	IFIX	2554	CALL
320	EXP	1274	MGET	2574	MPUT
366	CPEN	1334	SWIT	2636	MSAV
370	COMP	1366	PEN	2723	MTAK
403	LOOK	1454	TOTL	3164	MULT
406	CONV	1474	OUT	3326	CHAN
421	GRA	1555	NAME	3334	WHAT
662	ITR	1574	PUT	3356	DN
664	DIVD	1634	RIT	3357	DO
675	DIVM	1636	SAV	3404	SHFT
734	STAT	1674	SET	3407	GO
1004	LFT	1706	SGN	3426	IN
1034	EDIT	1723	TAK	3435	FORM
1040	MAX	1726	SIN	3443	ABS
1044	ICRT	2005	ZCOM	3444	ADD
1077	LOG	2034	SQT	3517	SHOW
1112	STOR	2052	SUB	3544	TAKL
1114	PLOT	2077	ILOG	3570	UP
1126	MIN	2154	PULL	3643	ASK
1153	MEMC	2163	UNC	3656	ATN
1155	MEME	2254	PUTL	3673	PAUS
1172	MEMR	2256	PUTN	3772	CLER
1177	MEMW	2302	REVR		

APPENDIX Z

SPECIAL FOCAL INPUT-OUTPUT OPERATIONS

for "LICK FOCAL"

The FOCAL system was designed to handle complex arithmetic operations using the typewriter for both input and output. However, in much of our work we need to use additional input-output devices, while keeping the programming convenience afforded by the FOCAL language.

Some changes have been made to the FOCAL system, to allow communication with specially written machine-language programs that take and store data, operate the plotter and disk and look after some awkward data manipulation.

The special operations are handled just like the ordinary FOCAL commands. They are written in the form - (a) SET D = FABC(ARG3, ARG4 --- ARG8) or (b) X ABC(ARG3, --- ---). The arguments ARG3 --- give the numerical values that define the exact details of the operation. Arguments not stated are always taken as zero. The numerical result (if any) of type (a) operations is placed in variable D. Numerical results can have values up to $\pm|2^{22}-1|$, while the arguments usually must not be greater than 4095 ($=2^{12}-1$). Non-integer arguments are taken as the next lower integer. The final argument of certain commands may be as large as $2^{23}-1$.

A summary of the currently available commands is given in the following pages. More detailed explanations of some of the functions are given in other Appendices.

need a list of DIRECT, ETC.

NB. TAN(A) doesn't exist.

FUNCTION LIST: "LICK FOCAL" SUMMARY

Set D = FITR(N)	integer value of N. (D is set equal to integer value of N)
Set D = FLOG(N)	log N (D is set equal to log N to the base e)
Set D = FSIN(N)	sine N
Set D = FCOS(N)	cosine N
Set D = FEXP(N)	exponential e^N
Set D = FSGN(N)	sign of N
Set D = FABS(N)	absolute value of N
Set D = FSQT(N)	square root of N
Set D = FTAK(B,W)	get single precision value of word W in disk block B.**
Set D = FASK(B,W)	get 10 digit floating format variable starting at disk word W, block B. (4 words used) - See X STOR( )

A special command "X" (execute) can be used for functions which need not return a number to FOCAL:

X PUT(B,W,I)	Store integer I* in disk word W, block B.**
X STOR(B,W;V)	Store variable V starting at disk word W (Note semicolon).
X GO(S,L) X DO(S,L)	Like ordinary GO,DO but with computed arguments. (Subroutine S, line L.)
X FILE(N)	File program N on DECtape.
X CALL(N,S,Q)	Call program N, start at subroutine S (if S>0). If Q = 1, calls can be nested to 10 levels. Nesting list is cleared for Q = 0.
X CALL(N,S*128 + L)	Start at line L, subroutine S , Program N.
X CALL(N)	Call program N, don't start.
X END(Ø)	Return to calling program; next line.
X SHFT(B,N)	Move disk block B to an address N words higher. $N < 2045$
X PEN(X,Y)	Move chart recorder X steps, then move pen to Y.
X SHFT(B,-N)	Move disk block B to an address N words lower. $N < 2045$

X MPUT(D,T,N,U) — Copies from Disk to Tape
- D: First disk block
- T: First tape block
- N: Number of blocks to transfer
- U: Tape Unit # (Ø and 8 are the same unit)

X MTAK(D,T,N,U) — Copies from Tape to Disk

Disk blocks 213 to 225 are changed. Atempts to treat disk blocks above block 210 will produce a diagnostic "DISK END" with these 2 instructions.

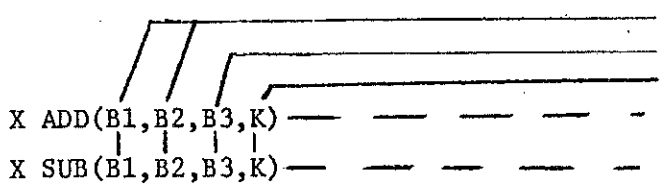
**If B=W=Ø, the previously used disk address will be incremented and taken as the current disk address.

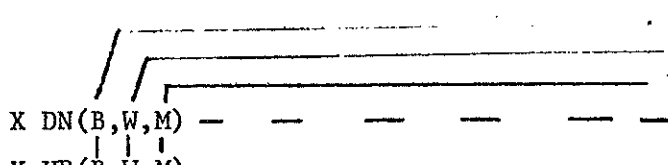
*Integers can have values $0 \leq I \leq 4095$

CALCOMP PLOTTER

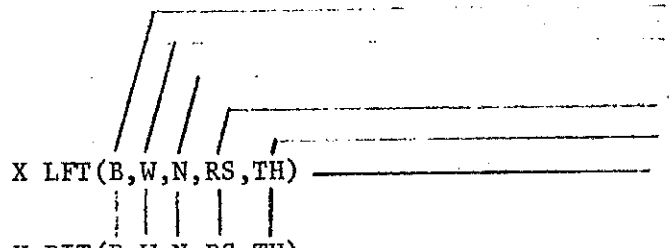
X COMP(X,Y,D)	Move a distance Y, then a distance X. Move diagonally if D = 1.
X CPEN(P,T)	P = 0: Pen Up. P = 1: Pen Down. Pause for time ~ 10*T msec. Pen motion needs about 100msec, which can be used for computation, or by the pause.
Set D = ZCOM(Y)	D becomes equal to the current Y location of the Calcomp pen. Location record is reset to Y.
X DIS(X,Y)	Store a dot on the CRT at location X,Y. (Full scale 1023)
X STAT(X,Y,S)	X origin ≠ 0 Y origin ≠ 0 Letter size Direct all future printing to the CRT. Redirect printing to teletype if X = -1 or for CTRL-C, or for any error diagnostic. (See Appendix G)
X SWIT(-1)	Erase CRT. (Wait for 0.5 sec before trying to write anything)
X SWIT(Ø,L)	Load lamps L. Lamps are coded 1,2,4,---32.
S D = FSWIT(N,S,Ø,Ø,M)	Read switch N,S to D. Set M = 4095 to read all group N at once. (M = 9 to read switch 1 & 8, weighted, etc.) M = 0 to read only switch N,S.
S D = FSWIT(3,11,X,Y)	Display joystick marker at X,Y. When switch 3,11 is pushed, return 1024*X1 + Y1 where X1,Y1 is final marker location. See Appendix J.
X NAME(N)	Replace disk overlay program #6 with a special user generated machine language program, #N.
X WHAT ~~(N)~~ M, N)	Type the names of N+1 user generated overlay programs as found on a program DECtape. (See Appendix N) starting at program M.
X PUTN(B,W,D,N,I)	First block First word First word content Word count Data increment for successive words Load disk with linear data.
X ICRT (0)	(Exchange X and Y axes for CRT plot command. Useful for drawing vertical lines.)

ADDITIONAL FOCAL COMMANDS FOR MICROPHOTOMETER





Move M steps of 4.5 micron each, record digitized amplifier output at each step in successive disk words. Full scale amplifier output is 1023.

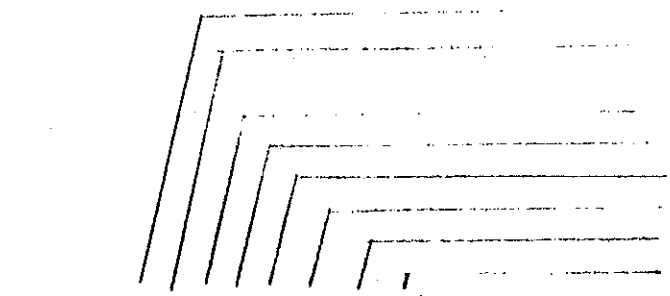


Set D = FUNC(B,W,K)

D becomes a function of disk word W in block B. Function tables are preset by X SET(A,Z). K/3096 is the fraction used of the second table. (interpolates between the two tables.) See Appendix F

X SET(A,Z) (A,Z nonzero)

Loads two 129 word function tables from blocks A,Z for use of FUNC( ), X PLOT( ), X IFIX( ).



Applies FUNC conversion to each data point, and outputs result to CRT or chart recorder.

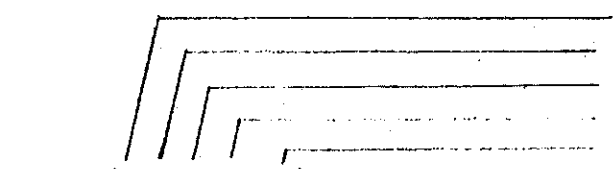
If L = 0; output is on strip chart.
If ND = 0; direct readings from the disk are plotted, without use of the function tables.

*See footnote next page.

*X IFIX(B,O,S,1,N,ND,NF,OF)

Used exactly like X PLOT( ), but output replaces original data on the disk, instead of going to CRT or recorder.

See Appendix H.



X MULT(B,W,N,G1,G2)

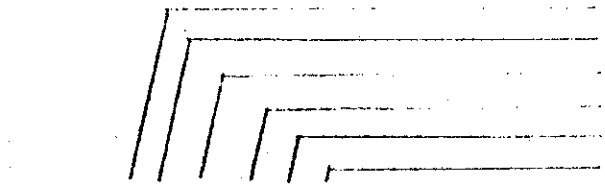
Multiplies N words on the disk by a number which varies linearly from G1/1000 to G2/1000, as it goes from the first to the last word.

X PUTL(B,W,N)

Stores double precision values of N ($N \leq 2^{23}$ (~8 x 10^6) on disk words W, W+1, block B.

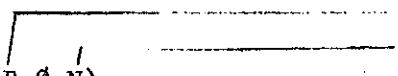
Set D = F TAKL(B,W)

Retrieves double precision data from disk.



X CONV(B,W,B1,W1,D,A)

Converts 129 double precision variables. V1 = V/D + A.



Set D = FMIN(B,Ø,N)

Returns the minimum value found in N blocks of the disk. (Single precision data)

X SMAX( )

SD = FTOTL( )

---

*USE X STAT(1,1) to initialize X,Y location
USE X SET(A,Z) to initialize function tables from disk blocks A,Z which represent the calibration at the ends of the 24 block data segments on the disk.

DIVM

ADDITIONAL FOCAL COMMANDS FOR SCANNER DATA REDUCTION

X CLER(B) — Clear buffer B to all zero.

X DIVD(0,B) — Normalize buffer B to single precision.

X DIVD(R,B,M,D,L,H) — Divides data in core buffer by data on the disk. (for 1 512 word x 24 bit scanner record).

- R — Record No. of Divisor on disk (prenormalized to single precision)
- B — "Buffer" No.
- M — Multiplier (1 for default)
- D — Divisor if R = 0
- L — Lowest channel treated
- H — Highest channel treated (511 for default)

X EDIT(C,B+100*R,K) — Replace content of channel C.

- C — Channel No.
- B — Buffer No.
- R — First record No. of extended buffer
- K — New content

X ERAS(L,B+100*R,N) — Clear N channels of buffer B to zero.

- L — Lowest channel No. treated
- N — Channel count

X IN(R,B) — Add disk record R into buffer B.

X OUT(R,B) — Subtract disk record R from buffer B.

X MGET(R,B,U) — Get record R into buffer B from DECtape unit U.

X MSAV(R,B,U) — Save buffer B as record R on DECtape.

X MOVE(L,N,S,I) — Partial channel shift (Buffer 1 to Buffer 0)

- L — Lowest channel No. treated
- N — Channel count
- S — Shift for channel L is S/1000
- I — Shift changes by I/1000 for successive channels

Set D = FPEAK(L,B+100*R,H,SP,SM) — Find highest channel, in up to 4096 channels.

- L — Lowest channel No. treated
- B — Buffer No.
- R — First Record No. of extended buffer
- H — Highest channel No. treated
- SP — Switch (to return channel No.)
- SM — Switch (to count monotonic increases)

(If SP is zero, get content of highest channel, otherwise get the channel No. If SM is non-zero, get the count of monotonically increasing channels starting at channel L.)

X PULL(R,B) — Recall disk record R into buffer B.

X SAV(R,B) — Save Buffer B as disk record R.

X CRT(SC,N,X1,B,SW,OF,P,D) — Plots on CRT or Calcomp

- SC — Full scale = SC*1024
- N — Number of points (512 in default)
- X1 — First word used
- B — Buffer No.
- SW — Sweep repetitions (1 in default)
- OF — Offset (full scale = 1023)
- P — Use Calcomp if P = 1
- D — Plot dots if D = 1

(Stops plotting if switch 3,8 is set)

Set D = FCHAN(C,B+1ØØ*R) — Loads D with content of channel C, buffer B.

First disk record No. of extended buffer

Set D = FTOTL(C,B+1ØØ*R,N) — Gives total of N channels in buffer B starting at channel C. (triple precision)

ADDITIONAL FOCAL COMMANDS FOR SCANNER DATA TAKING

X MEMC(T) — Count for T scan cycles *(4.096 msec each) Stop counting if T = 0. Elapsed time is about 4.4 msec per cycle.

Set D = FMEMC(1) — D becomes "1" if scanner is counting.

X MEME(Ø) — Erase the scanner memory.

X MEMX(1) — Load "X" scan-program memory (512 word) from buffer 1 and enable the linear sweep. The X program cycles once per complete scan cycle.

X MEMX(Ø) — Load "X" scan-program memory from buffer 1 and disable the linear sweep. The X program cycles 8 times per complete scan cycle.

X MEMY(Ø) — Load Y scan-program memory (512 word). The Y program cycles once per complete scan cycle.

X MEMR(W,Ø,H) — Read 1024 channels into core memory starting at scanner Channel W. Lower 512 channels to buffer 1, second 512 to buffer Ø. If H is non-zero, reads only the low-order 12 bits to save time. (1Ø24 channe

X MEMW(W,N,OR) — Writes N 12 bit words from core buffer 1 into scanner memory. If OR = Ø, low-order is loaded, if OR = 1, upper 12 bits of memory is loaded. (Useful for hardware checkout).

X FORM(N) — Convert data in core buffer from 1Ø24 channel format into 512 channel segments. Compresses N channels of data into each resultant channel.

X origin
Y origin
Spacing between lines
Number of channels (up to 1024)
Counts per dot
First channel used

X LOOK(X,Y,ST,N,SC,CH) — Draw an intensity map. (Uses low 12 bits only; 1024 channel format)

First channel treated
No. of channels

X REVR(W,N) — Reverses the channel sequence.

X PAUS(N) — Interrupt counting if N = 0, continue with no change in elapsed time record if N = 1.

*In one "scan cycle", the scanner tests 4096 locations on the image tube, with the possibility of adding counts to words in the 4096 word memory.

Description of Arguments for Scanner Commands

Note that all storage assignments are by record and buffer number. A given record or buffer No. is always stored in the same physical location.

B - Buffer number Ø or 1. Buffer Ø uses memory area 14000 to 15777. Buffer 1 uses area 12000 to 13777.

C.- Channel number in a buffer.

R - Data record number. Each record uses 8 blocks on the disk or tape. The first disk block number of each record is 8 x R. The first 512 words of any record contain the lower precision and second 512 words contain the upper precision words of a 512 channel spectrum segment (28 records fill the disk, with blocks 224, 225-free, 226 ff used for program overlay.) 144 records fill a Dectape.

S - CRT display full scale. Each channel content is divided by S before being displayed. (full CRT deflection for 1023 counts if S = 1. e.g., X CRT (10) for full scale 10230.

N - Data channel count. Spectra in a non-extended buffer have channel numbers going from 0 to 511. Channel numbers up to 4095 can be used in extended buffer.

K - When replacing the content of a channel in memory, numbers up to $\pm|2^{22}-1|$ can be used.

T - Counting Time in units of scanner sweep period. (4.096 milliseconds per sweep.) Numbers up to $2^{23}-1$ are acceptable.

U - Tape Unit No. Usually either 7 or 8. [Unit Ø does not exist; references to unit Ø will actuate unit 8.]

Data Scales

Double precision PDP 8 words can hold numbers up to ~~1,677~~16,777,215($2^{23}-1$). However the most significant bit is treated as a minus sign by FOCAL, so that values above 8,388,607 will appear as negative numbers when used by FOCAL'S arithmetic routines. The FTOTL(--) command can handle numbers greater than 10^{10} without overflow.

NOTES ON USE OF DISK AND TAPE COMMANDS

A. If the arguments for disk word and block are both zero the system will always increment the most recent disk address, and use that for the next disk address. This allows easy reference to a long string of disk words.

B. Disk Blocks are 129 words long. In a disk address, "Block B, Word W"; W goes from 0 to 128 in one block. An address: block 91, word 129, for example, is exactly the same as block 92, word 0. Both addressing modes could be used interchangeably and the same disk word would be accessed in either case. (W must be less 4096).

C. Restrictions on X CALL(N). X END(N). for program chaining:
The X CALL( ) and X END( ) commands must not be used within a DO loop.

D. Nested program chaining is possible in FOCAL, provided each nested call is written as X CALL(N, S, Q), Q > 0; the nesting list is reset when Q = 0.

SECTION III. Spectrograph Preparation and Use

A. Setting Up the Instrument to Observe

1. Turn on Refrigeration Unit
2. Computer Room. (See V.E.1)
   a. Turn on main power switch to computer.
   b. Turn on: i. port-hole 'scope; power switch is on SCALE ILLUM
      ii. memory 'scope; after it is warm hit ERASE
      iii. scanner memory (EL-703). Set number of scan lines to 8 for double slit, 4 for single slit. For the C.A.T., set number of scan lines to 4 for double slit.
   c. Insert floppy disk #EP-14 in a disk drive set as unit 0 and set to WRITE ENABLE.
   d. Bootstrap FOCAL. (See V.E.1.d.)
   e. Go to the coude' pit and turn on the sweep box (EL-430).
   f. Set switch 1,1 to INITIALIZE DATA TAKING, type G then RETURN, then follow the instructions. As a temporary set-up for finding wavelengths, put an empty disk in the other drive set to unit 7 and set to WRITE ENABLE, answer 0 for all the scan numbers, and answer "N" to the LOG ID question. Be sure to load some sweeps! If sweep loading fails, you have probably forgotten to turn on either the sweep box (EL-430) or the scanner memory (EL-703). If that's not the case, something serious is wrong and you should call Mr. Deitsch.

NOTE: The scanner memory in the computer room (EL-703) and the sweep box in the pit (EL-430) should both be either on or off at the same time, and if they are on sweeps of some sort must be loaded. If this is not done, the sweep circuitry goes in a random fashion, resulting in overheating and eventual destruction of circuit elements.

3. Coude' Room (See V.C)
   a. With power off to image-tubes and dissector, open the dark slide to the front face of the image-tube chain. Check for dirt or film on the window. If so, try cleaning it with lens tissue and ethanol.
   b. On the east side of the I-beam are buttons to control the collimator/cross-disperser lift. Push LOWER.
   c. Hanging on a hook near those buttons is a paddle to control the Echelle arm.
      i. Rotate the arm (push the toggle toward USE) until it is parallel with the I-beam.
      ii. Push DOWN. While the arm is descending, carefully remove the grating cover which is held by two bolts.
      iii. There are two braces necessary to secure the Echelle arm in its final position. The lower, or horizontal brace, is round and about a meter long, and is stowed up against the I-beam just to the west of the collimator/cross-disperser lift. The upper, or vertical brace, is directly overhead against the I-beam as you stand near the door to the loading room. Lower this vertical brace from its perch and let it dangle vertically.

iv. Further rotate the Echelle arm in the USE direction until it just touches the vertical brace.

v. Now remove the horizontal brace from its perch and carefully swing it around past the collimator/cross-disperser lift and 20-inch camera so that the cone on its end is pointing upward and is just beneath the Echelle grating. Rotate the Echelle arm as necessary so that this machined cone fits as snugly as possible into the corresponding female piece on the Echelle arm. DO NOT SCREW IN THE BRACE UNTIL YOU ARE THROUGH MOVING THE ARM.

vi. Once the arm is in the right place, screw in the knob so it's snug, but don't force things if they won't go willingly; there's unusually a reason. At the other end of this brace is a spoked wheel to be tightened after the Echelle end is secure.

vii. Now screw down the vertical brace snugly.

viii. Climb up the aluminum ladder beneath the slit plate and lower the small flat mirror into place. It is held by a black thumb-screw that is near where the arm swivels and on the east side. Raise the arm slightly with your left hand to take the weight off of the screw, then loosen it a few turns and lower the mirror gently against its stop. Remove the grey plastic cover by pulling it straight off.

ix. Open the door on the collimator/cross-disperser lift and carefully open the cover on the Echelle grating. Note which cross-disperser is directly underneath the collimator for later reference. If the rod that sticks out the west side of the collimator/cross-disperser housing is fully in, the "G" grating is in place, otherwise the "R" grating is in place.

x. Rotate the conventional grating turret so that the slot cut out of the disk is on east side of it. This prevents vignetting of the Echelle spectrograph beam by the turret.

xi. Be sure all the lights in the coude' and loading rooms are off before leaving.

4. Coude' Pit. (See V.A and V.B)

a. Sweep box (EL-430) should already be on. Set number of scan lines to 8 for double slit, 4 for single slit. For the C.A.T., set number of scan lines to 4 for double slit.

b. The image tubes are stored with 16 kV on them at all times. Turn this up to 36 kV as indicated on the large meter above the 50 kV power supply. The knob to the left of the meter controls the voltage.

c. The HP 4 kV power supply thumbwheels should be set to 2840 V. Just turn on the power switch. If the voltage meter fails to show results, try turning the CURRENT knob slightly.

d. The fan on the sweep box oven should ordinarily be ON.

e. Push RESET on the multiplexer (EL-331).

f. The dry nitrogen gauge (topmost of the two) should indicate a pressure of around 3 inches of water, but any non-zero setting should be all right. If the gauge reads zero there can be serious consequences, and this fact should be called to the attention of Mr. Laub or Mr. Owens.

4. Coude' Pit (Continued)
   g. The Refrigeration unit at the back of the pit should be on, and the pressure gauge should imply a temperature of -20 to -30 Celsius. This temperature can be checked by using an ohmmeter on the points indicated on the electronics rack. This resistance can be converted to temperature by using the chart.

      If these conditions are not fulfilled, call Mr. Laub or Mr. Owens.

5. Slit Room. (See V.D)
   a. Turn on the grating driver box at the east end of the room (EL-653), then push CALIBRATE. The number displayed for the focus may not agree exactly with that on the thumbwheels; this is of no consequence and should be ignored.
   b. Move the comparison lamp stage so that the thorium and tungsten lamps are in position.
   c. Remove the slit cover and the small plate below the slit that covers the moonlight-eliminator holes.
   d. The lower prism/decker is stored in the left cabinet in the computer room. Mount it on the slit pedestal into the holes just below the slit. Lay the prism back toward you as you insert it. DO NOT ALLOW ANY PARTS TO CONTACT THE SLIT. One of the moonlight eliminator holes is left exposed and should be covered with black opaque tape.
   e. Select the decker desired (usually decker #1 for the C.A.T., #2 for the 120-inch).
   f. Set the slit as desired. 200 to 500 microns is suggested.
   g. Set the behind-the-slit decker to 10 to 30 mm.
   h. Remove the protective cover from the dark slide knob by unscrewing. The dark slide is below the slit and to the east, over by the calibration filter knobs.
   i. Turn on the remote display 'scope. The traces will center once it is warmed up. If you wish, the cables allow you to place this anywhere in the room, e.g., near the observer's chair so the intensity can be turned very low.
   j. Everything should now be ready. As a test, set the counting time on the computer (switch 1,7) to 2 minutes, then push START (switch 3,9). With 4 scan lines of 1024 channels each, there should be a dark current of 6,000 counts total or less per scan line in the 2 minutes. If it is higher, consult the troubleshooting section.
   k. Put in a filter behind the slit. When working redward of λ5100, a GG 495 is commonly used. Blueward of λ5100, you will have to think carefully about what filter you need. Generally, the cross-disperser, when used in first order, will provide all the order separation necessary (second order is in the u.v. where the tube is not sensitive). But owing to scattered light, it is best to eliminate the red with, for example, a BG38.
   l. Cover the access hole to the filter behind the slit with black tape.

B. Finding a Wavelength

1. Calculate the Grating Positions.

The computer at this point should be in a data taking mode because you have gone through INITIALIZE DATA TAKING and have loaded sweeps. Hence set switch 4,1 to position 1 (GRATING SETTINGS) and depress 3,7 (B FUNCTIONS). Enter the desired wavelength and wait a few seconds for the calculations to be made. It is useful here to consult the graph of spectrograph efficiency versus wavelength to determine the best Echelle order for the desired wavelength. The "R" or "G" after the cross-disperser position indicate which grating to use--the R grating is blazed at 7500, the G at 5000.

In some cases two Echelle positions will be calculated if the wavelength selected is near the end of an order. If the Echelle setting is large number (20,000 or more) the dispersion will be high, and if the setting is small (less than 10,000) the dispersion will be low. I recommend the low dispersion setting for most applications.

2. Select the Cross-Disperser

a. Make sure the dark slide in front of the tubes is CLOSED.

b. Go into the Coude' room. The rod that projects from the west side of the collimator/cross-disperser housing selects the grating. If it is all the way in,the G grating is in place. To change gratings, pull up on the knurled knob with your left hand and move the rod with your right. Release the knob once the rod has been moved slightly; it will then fall into the detent when the correct position is reached.

Leave the room as before. Be sure the door to the collimator is fully open and that all lights are off.

3. Position the Gratings

This is done with the grating driver box (EL-653) in the slit room. Set the thumbwheels to the desired positions. The large green buttons labeled ECHELLE and CR DISP move the gratings. Push ECHELLE. The grating will move until it reaches the desired position and it should take out backlash. On rare occasions the grating will move in the wrong direction or will go past the correct position. If this happens, push the red STOP button, then push ECHELLE again.

Now push CR DISP. The same rules apply. If at any time the controller does something amiss, push STOP and start over.

4. Check the Setting

a. In the slit room, under the grating driving box, is the "tungsten" lamp power supply. Turn it on and adjust the pot to about 4V. Put the decker in place over the slit, but have the lower comparison prism out of the way. Bring the upper comparison prism into position by releasing the slide which it is on and gently lowering it. The catch for the slide is on the west side, up and under.

b. Open the dark slide.

c. Go to the computer room and set the counting time (1,7) to 32 minutes and set the display switch on the scanner memory to REMOTE. Go back to the slit room.

d. Push START (3,8) and open the shutter. Be sure the toggle on the comparison timer is set to TIME.

4. Check the Setting (continued)
   e. Look at the display 'scope. One wants all 4 to 8 sweeps to get roughly equal amounts of light and they should be getting a lot. If not, move the cross-disperser around to center the spectrum on the sweeps. Try moving 10 units at a time. You may have to move the cross-disperser as much as 300 units until the spectrum hits the sweeps.
   f. If the sweeps are grossly out of tune with the tungsten, go set new sweeps (III.C)
   g. When the spectrum is properly centered, close the shutter and push the comparison prism slide up until it catches. Turn on the thorium lamp and set to 20 ma. Set the comparison toggle to FOCUS.
   h. Push START to erase the CRT and start a new scan, then open the shutter. If you are at a very strong line, close the shutter right away, otherwise integrate for awhile to define the lines better.
   i. Compare this spectrum with the thorium charts in the computer room. Remember that red is to the right on the CRT, blue to the left. These charts were made at lower resolution.
   j. If you are lucky, you are right where you want to be, but in general some corrections have to be made. If you can determine where you are in the spectrum, you know which way to go and how much. Moving the Echelle grating toward higher numbers takes you to longer wavelengths, but for the cross-disperser the sense is reversed. Moving the Echelle about 100 units moves the spectrum about one screen width. Don't move the gratings too much at one time or you will lose the spectrum from the sweeps. If you do lose the spectrum, go back to step a. Try moving the cross-disperser about 10 units for every 100 Echelle units, but in the opposite direction.
   k. Once you have centered the desired wavelength, corrected for radial velocity if necessary, on the tube face, you can check the setting if and only if the sky is clear.
      i. Open the upper shutter on the C.A.T.
      ii. Bring the CAT flat into place over the slit and open it.
      iii. Open the shutter with the T handle directly above you.
      iv. Take a sky scan and compare with the Utrecht atlas which is in the slit room.
   l. Now that you have your wavelength centered, you need to set accurate sweeps.

C. Setting Sweeps.

1. Slit Room.
   a. Turn on the tungsten lamp and bring in the upper comparison prism as explained in III.B.4.a.
   b. Set slit to 150 to 200 microns.
   c. Open the dark slide and shutter.
2. Computer Room
   a. Set 1,1 to position 4 - SET SWEEPS. If using a double decker, raise 4,9. Type CTRL-C,G, RETURN.
   b. SET scan count switches. This parameter ranges from 2 to 64 on a rotary switch on the scanner memory (EL-703). Set to 4 lines if using the single decker or the narrow (CAT) double decker. Set to 8 lines if using the wide (120-in) double decker.
   c. Answer the queries as appropriate.
      i. "MAP TUBE? (Y/N)". Ordinarily you will wish to see where the light is falling relative to the sweeps, so answer "Y", but occasionally you may just want to see what the sweeps look like, in which case "N" would be appropriate.
      ii. "FULL OR NORMAL VIEW." The higher magnification, "Normal" view should contain the spectrum if you have done a rough centering with the grating controller in the slit room.
      iii. "COUNTS PER DOT." Try about 10 for starters. If this isn't appropriate, hold down switch 3,12 and you will get another chance.
      iv. Now the tube will be mapped and displayed on the memory 'scope. Horizontally, the 26 mm of the tube face is shown, but vertically the scale is expanded so that only a small portion of the tube is shown. Eight of the broad bands displayed during the mapping equal one millimeter on the tube.
      v. When as much of the tube has been mapped as you care to see, hold down 3,11 a few seconds until something happens (the floppy disk drive will click). If you want to start the mapping over, push 3,12 which takes you back to step iii (push ERASE on the memory 'scope if you do).
      vi. "SWEEP # (-1 NO CHANGE,...".
      Entering -2 allows the sweeps to be automatically set by the computer. This works well and is generally used, rather than manually setting sweeps.
      Entering -1 does nothing and takes you to the next step.
      Entering 1 through 7 recalls sweeps stored on the program disk, displays them and then goes to the next step.
      Entering 0 allows you to set new sweeps:
         1. "SET SCAN COUNT SWITCHES" - you have already one this.
         2. "TRACE (B)OUNDARY, (C)..."
            a. entering "B" means you wish to trace the two edges of the visible spectrum (this option works only for the single decker). The program computes spacings for the sweeps so that the area between the two lines you traced is evenly covered. This option is not recommended.
            b. entering "C" means you wish to indicate the apparent center or centers of the spectrum (this option works

C. Setting Sweeps. (continued)

for any decker). If switch 4,9 is up the program expects you to trace two centers. Using the known vertical scale on the tube, the program computes sweeps so that 1 mm is covered on the tube. This is the best option to use.

c. entering "L" means you wish to trace individual lines.

In all cases, mark the desired path using the joystick and 3,11. In the L option, previous lines can be copied by moving the cursor to the box indicated in the upper left screen. Remember that offsets are negative if you are working downward on the screen.

viii. "CURVES OK? (Y/N)". If you are satisfied with the sweeps, answer "Y". An "N" response sends you back to step vi.

ix. "SAVE AS SWEEP NO". If you called these sweeps from the disk, use the same number to store them again. If they are new sweeps, use any number from 1 to 7.

x. "SWEEP n ALL SET". This is the usual reply. If the reply is "LOADING FAILED", the general cause is that either the sweep box (EL-430) or the scanner memory (EL-703) is not on. If they are on and the sweeps won't load, something serious is wrong and you should call Mr. Dietsch.

xi. "RESET SWITCH 1,1...". You have probably already initialized data taking, so set to CONTINUE DATA TAKING.

D. Taking Data

0. Just before taking the comparison and etalon scans at the beginning of the night, it is best to touch-up the cross-disperser position to center the spectrum vertically on the sweeps.

1. Set the desired dwell time on 1.7. To change the counting time once a scan has been started, push 3,11.

2. Be sure a data tape is available on unit 7, set to WRITE ENABLED.

3. Use switches 3,8 3,9 and 3,10 to control scans as explained in V.E.7.

4. Record the Universal Time and Hour Angle at the beginning of the scan on a log sheet and enter this information into the computer if you have selected that option.

5. When using the double decker, alternate the star between the deckers on successive scans. It is suggested that you do an even number of scans per star to simplify background subtraction.

6. Have as little light as possible on in the slit room while observing; the image tubes are very sensitive.

Section IV. Stowing the Spectrograph

A. Slit Room.
   1. Close the dark slide and shutter.
   2. Turn off the grating driver box (EL-653).
   3. Turn off any comparison lamps and the rack power.
   4. Dismount the prism assembly and return to the cabinet in the computer room.
   5. Cover the moonlight-eliminator holes.
   6. Cover the slit.

B. Computer Room.
   1. Dismount tapes and disks.
   2. Turn off:
      i. port-hole 'scope
      ii. memory 'scope
      iii. scanner memory (EL-703)
      iv. main power switch on computer
   3. List any problems in the log books.

C. Coude' Pit.
   1. Leave dry nitrogen running.
   2. Turn refrigeration unit off.
   3. Turn down tube voltage to 20 kV.
   4. Turn off dissector voltage.
   5. Turn off sweep box (EL-430).

D. Coude' Room.
   1. Close door on collimator/cross-disperser lift, then push RAISE.
   2. Carefully close the cover on the echelle grating.
   3. Remove the horizontal brace from the echelle arm by loosening at both ends, then stow it up against the I-beam near the 20-inch camera.
   4. Loosen the vertical brace from the echelle arm and leave dangling.
   5. Rotate the echelle arm in the STOW direction until the arm is parallel to the eastern I-beam.
   6. Push UP. The arm will not raise unless a microswitch on the lift is depressed by a tab on the arm.
   7. While the arm is lifting, put the dust cover over the grating.
   8. Put the grey plastic cover on the flat mirror above the image tubes. Raise the mirror arm fully up with the left hand, then tighten the black thumbscrew on the east side of the arm near its pivot. Lower the mirror against its stop.
   9. Rotate the echelle arm (once it has been fully raised) in the STOW direction until it is about one inch from the big green pipe. Stow vertical arm.
   10. Turn off all the lights as you leave.

VISITOR'S OBJECTS

36" REFRACTOR

		1985 C.O.	
	GALAXIES		
NGC-221	M-32	00-41-54	+40 47
NGC-224	M-31	00-41-54	+41 11
NGC-1068	M-77	02-41-53	-00 05
NGC-3034	M-82	09-54-48	+69 46
NGC-4565	--	12-35-38	+26 04
NGC-4594	M-104	12-39-13	-11 32
NGC-5194	M-51	13-26-16	+47 16
	PLANETARY AND GASEOUS NEBULAE		
NGC-1952	M-1	05-33-36	+22 00
--------	M-42	05-34-32	-05 24
NGC-2440	--	07-41-09	-18 09
NGC-3242	--	10-23-59	-18 33
NGC-6210	--	16-43-50	+25 50
NGC-6514	M-20	18-01-01	-23 02
NGC-6523	M-8	18-02-14	-24 22
NGC-6543	--	17-58-35	+66 37
NGC-6618	M-17	18-19-55	-16 11
NGC-6720	M-57	18-53-00	+33 00
NGC-6853	M-27	19-58-54	+22 40
NGC-7009	SATURN NEB	21-03-18	-11 28
NGC-7662	--	23-25-04	+42 23
	GLOBULAR CLUSTERS		
NGC-5024	M-53	13-12-12	+18 14
NGC-5272	M-3	13-41-30	+28 27
NGC-5904	M-5	15-17-46	+02 08
NGC-6205	M-13	16-41-09	+36 29
NGC-6218	M-12	16-46-25	-01 55
NGC-6341	M-92	17-16-40	+43 09
NGC-7078	M-15	21-29-17	+12 06

	OPEN CLUSTERS	1985 O.D.	
NGC-475	---	01-08-09	+58 14
NGC-663	---	01-44-54	+61 10
NGC-869	---	02-19-40	+57 04
NGC-884	---	02-22-53	+57 02
NGC-1912	M-38	05-27-38	+35 49
NGC-2099	M-37	05-51-23	+32 32
NGC-2168	M-35	06-07-56	+24 20
NGC-2437	M-46	07-41-06	-14 46
NGC-2682	M-67	08-49-42	+11 52
NGC-6494	M-23	17-56-03	-19 01
NGC-6705	M-11	18-50-16	-06 17
NGC-6838	M-71	19-53-03	+18 44
NGC-7243	---	22-14-28	+49 48
NGC-7789	---	23-56-16	+56 37

PHOTOGRAPHIC PLATE BAKING USING FORMING GAS.

During the year 1982, a Blue-M baking oven was purchased and set up in the basement of the present recreation hall. A number of metal baking boxes were also constructed, so that it is now possible to bake most spectroscopic photographic plates at Mount Hamilton. The procedures follow those used at Kitt Peak National Observatory.

The following instructions and guide lines are to assist those baking plates.

PLATE STORAGE

1. In the basement of the recreation hall are also located eight deep freezers that are used to store the photographic plates used on Mount Hamilton.

FREEZER #1: Contains plates that have been cut to special sizes and also baked plates ready to use.

FREEZER #2: All the 5X7-inch plates and also older 8X10-inch plates.

FREEZER #3: All the 4X6-inch plates and also plates that astronomers have in their own special containers.

FREEZER #4: All the latest vintage 8X10-inch plates.

FREEZERS #5 and #6: Are still in Shane telescope building, storing special equipment.

FREEZER #7: Contains plates used mainly on the 20-inch Astrograph, and is used to store baked plates in their bake boxes.

FREEZER #8: Large plates used at the 20-inch Astrograph.

BAKING PROCEDURE WITH 2% FORMING GAS

1. Take the necessary plates from Freezer #4 to the plate cutting room, located directly behind Freezer #1, and allow them to warm to nearly room temperature. This usually requires about three hours.

2. After the plates have warmed, they may be cut to the desired size, and placed either directly in the plate baking box or in a removable rack that is then placed in the bake box. (Usually the bigger plates go directly into the boxes, while the smaller ones go into the special racks.) The boxes and racks are stored on a table in the freezer room.

3. Put the lid on the bake box. When it is in place, one may use a flashlight to line up the match marks. The lid may then be bolted on, and all bolts tightened with the special wrench furnished.

4. Take the loaded box to the table in the freezer room and attach the blue hose to the proper fitting on the bake box. (Notice there are two fittings: the other is a bypass valve so gas may flow through and out the box.) At this point be sure both valves are open.

5. Notice as you face north there are two tanks chained to the wall. The right-hand tank contains dry nitrogen, while the left one contains forming gas (2% hydrogen, 98% nitrogen). On top of the nitrogen tank is a

valve which, when turned counter clock wise, lets gas flow to the regulator on the left, through a valve with a black knob and to the right-hand of the 2 flow-meters located on the wall, thence to the bake box.

6. Turn the regulator control (T-handle) counter clockwise until it feels free. Turn the black knob directly below the control counter clockwise several turns and then turn tank valve counter clockwise about one half turn. Notice that the right hand regulator gauge now shows pressure. Turn the regulator control clockwise and set left hand gauge to read about 10 lbs. pressure. NEVER turn on tank pressure unless the regulator control is fully open (counter-clockwise). Damage WILL OCCUR if pressure is put against the regulator when it is partially closed. Adjust the flow meter to 2.0 (units are cubic feet per hour), and allow gas to flow through bake box for the necessary time: 15 minutes in the larger boxes to as little as 5 minutes in smaller boxes.

7. After the necessary purge time is completed, first turn off the box exhaust valve and then the inlet valve to prevent room air from entering the box.

8. Put the box in the bake oven and connect the hose inside to the inlet valve on the bake box.

9. At this point follow instruction #6 but now for the forming gas bank, except in this case, set the pressure to only 6 lbs. Set the flow meter, (in this case the left hand one) to a flow of 2 cubic feet per hour.

10. Open both valves on the bake box several turns so that forming gas may flow through the box, into the oven and out into the room.

11. Turn on the bake oven and check temperature after about one hour. It should be between 60° and 65° cent. If change in temperature adjustment is necessary, try to get E. Harlan to do this. If he is not available read carefully the instruction manual, taped to the oven in a manila envelope. If done incorrectly, the calibration will be lost.

12. Turn off nitrogen supply by following instruction #6 above. Be sure to turn off tank first so pressure will flow out of system.

13. The baking time for the plates on hand is 2-1/2 to 2-3/4 hours, plus one hour general warm up time. Feel free to modify this time to your own taste.

14. After baking time is completed, turn off the two valves on the bake box, pull off the hose, and turn off the bake oven.

15. Put the box on the table and connect the blue hose to the proper fitting and again follow instruction #6, letting nitrogen flow for at least 15 minutes as so to be sure all forming gas has been driven out of the box.

16. Shut off exhaust valve and pressurize to 3 lb. according to gauge in box (never over 5 lb!). Then close inlet valve. The box can then be taken away or stored in the #7 deep freeze.

17. Be sure the nitrogen and forming gas tanks are shut off. No extra forming gas is kept on the mountain.

18. After a few plates are removed from the bake boxes, if some remain, then the boxes must be purged and repressurized. At the present time, there are three places to do this: the plate baking room, 20-inch Astrograph, and the 120-inch coude dark room.

19. Plates should not be kept at room temperature for extended periods of time. This causes undue speed loss. Return the plates to a deep freeze as soon as possible. It is said they should keep for thirty days but at this time it is not known whether this is so.

E.A. Harlan

1/3/83

TELEPHONE CONVERSATION

Lick Observatory

Name _____

Company/Agency/Unit/Address _____

Telephone No. _____

Incoming _____ Date _____

Outgoing _____ Time _____

Subject/Project _____

Recorded by _____

Copies to (Name & Date) _____

Discussion Notes _____

LICK PDP 8/I COMPUTERS

Lloyd Robinson
August 1971

THE LICK OBSERVATORY PDP 8/I COMPUTERS

Introduction

a) Description

Two PDP 8/I computers have been installed to aid in data acquisition and reduction, as well as for use in small computing jobs. One machine is at the 120-inch telescope on Mt. Hamilton, the other is attached to the microphotometer at Santa Cruz.

Each computer has an 8K 12 bit memory, a 32K magnetic disc, an ultrareliable miniature digital magnetic tape "DECTAPE", a large screen Type 611 memory oscilloscope, and a teletype, together with special hardware interfaces that allow the computers to accept data from special devices such as the microphotometer, and the image tube scanner, and from specially designed digital apparatus.

b) Using the Computer

Each user of the machine will normally have his own magnetic tape (DECTAPE), which contains his programs and operating system. A hardware "bootstrap" circuit in the PDP-8 will automatically load the computer memory from the magnetic tape so that any special operating procedure by one user should not affect the behaviour of the machine for the next user.

A magnetic tape ("USER" Tape) containing standard programs will be kept in the same room as the PDP-8. This can be used by those who do not have their own programs or their own tape. Copies of this tape can be made by those who want a private tape.

CAUTION: As a precaution, the "USER" tape should be used with the "write lock" switch setting on the tape transport. If operations requiring writing of data on tape are to be done, obtain a private tape.

c) Programming the Computer

An exceptionally simple, easy to use program language called "FOCAL" (similar

to BASIC) can be loaded into the computer from the magnetic tape. Special commands have been added to make the language more suitable for our work and the new version has been named LICK FOCAL AUG. A summary of the standard commands is given in Appendix A, and a list of special commands is given in Appendix C. A number of manuals giving detailed descriptions of the language are available.*

Some Features of LICK FOCAL

- Conversational mode of operation.
- 10 digit precision, floating exponent 10^{-616} to 10^{+616}.†
- Programmable single variable-addressed storage of up to 8192 10-digit floating point variables on the disc.
- Programmable storage of up to 32,768 4-digit (<4096) word-addressable integers on the disc.
- Chaining commands that allow one program to call another from the magnetic tape. Subroutines may also be called from tape.
- Easy program-loading, and program-storage procedures.
- Programmable transfer of data between DISC and DECTAPE.
- LOG, EXP, SIN, COS, SQUARE ROOT functions.
- External devices such as microphotometer, CRT display, chart recorder, disk, and tape are under FOCAL language control.
- Additional special FOCAL commands can be added to deal with new hardware, or to carry out special operations in machine language.

† Some functions: SIN, LOG etc., give only 6-digit precision.

* Copies of these manuals are available from Digital Equipment Corp., Palo Alto. Some may also be found at the Santa Cruz Computer Center.

1. Advanced FOCAL
2. Introduction to Programming - Chapter 9
3. Programming Languages - Part 2
4. Disk Monitor System

Start-up Procedure

i. FOCAL User's

1. Turn on power switch (key).
2. Place a "FAST" user's tape on left hand spool of DECTAPE transport marked 8. Be sure each tape transport is selected to a different number.
3. Set tape switches to write-lock, local. Press button under right arrow for about 5 seconds to move tape past the "end zone".
4. Bootstrap procedure: on computer console, set address 200 (marked with red dot). Press "STOP".
   Press "LOAD ADD"(ress)
   Press "DEP"(osit)
   Press "LOAD ADD"(ress)
5. Press lucite "bootstrap" button on left side. Check that the teletype is "ON-LINE". Press "START".
6. Tape will spin for a few seconds, the disk contents will be checked for parity errors, rewritten if need be, and the teletype will print "*". FOCAL is now loaded and ready for use. (With some special purpose tapes, a program may start automatically.)

ii. System Programmers: (Master tapes)

The "FAST" tapes are used only for FOCAL programming and do not include the DECTAPE monitor. "Master" tapes also are available which contain both DECTAPE and DISC monitors. The DECTAPE monitor can also be bootstrapped using the procedure above. (See step 4 above) FOCAL can be loaded from a Master tape, but care must then be taken that FOCAL tape-writing commands do not overwrite source programs, etc. which may be stored there.

The contents of Master tapes normally include 3 or 4 separate copies or "images" of the 32K disk. These images may include machine-language source-programs for the FOCAL system plus Assembler, Editor, and the Peripheral Interchange Pro-

gram (PIP).

To load the Disk monitor:

1. Bootstrap a master tape. Teletype types "."/DECTAPE monitor is ready when
2. Type GETT(Return)
3. Teletype says ---- FILE NO(Ø--4)
4. Type no: 1,2,3 or 4.
5. Tape will spin for about 30 seconds.
6. When teletype types ".", type DISC(Return).
7. DISC monitor is ready when teletype types "."

Saving FOCAL Programs

After a program has been entered into the computer, it can be stored on DECTAPE for future use.

1. Set DECTAPE to WRITE ENABLED
2. Type X FILE(N)(Return); where N is a program number between 0 and 25. (If data is not stored on the tape, N may be as high as 168.)
3. The teletype will print the last address used for text storage. If a program number N already exists on the tape, the teletype will type OK?, unless that program has just been called from tape. If the previous program (or perhaps old data on the tape) is to be over-written, type "Y".
4. To recall the program, type X CALL(N)(Return)
5. To recall it and start automatically at subroutine S, type X CALL(N,S) (Return)

CAUTION: If a non-existant program is inadvertently called, FOCAL becomes deranged, and can only be cured by calling a real program, or by repeating the bootstrap operation. Attempts to ERASE, MODIFY, or ADD TEXT will lead to total confusion.

Storage on DISC and DECTAPE."FAST" System

The DISC and DECTAPE can be used for storage of both programs and data. In order to avoid possible loss of data or programs, and yet make fullest use of the available storage areas it is important to understand how storage areas are allocated.

The DISC and DECTAPE are subdivided into "Blocks" each of which contain 129 12-bit computer words. The disc has 253 (375 octal) while each tape has 1473 (2701 octal) blocks. Each block of tape can be addressed and modified without changing any other block. Each word on the disc can be independently modified.

The FOCAL system on "FAST" tapes reserves part of the tape for program storage and allows the user to allocate the remainder of the tape to either data storage or program storage. The tape utilization is as follows:

Octal Block Number		Allocation
0	:	DECTAPE Bootstrap
1 - 37	:	FOCAL Field 1
40 - 71	:	Overlay programs for top 24 blocks of DISC
72 - 131	:	FOCAL Field Ø
132 - 157	:	Reserved for system expansion
160 - 477	:	Programs 0 - 25 (8 blocks per program)
700 - 1277	:	Single block storage using X TAD( ); X DIT( )

Scanner Only		Microphotometer Only
500 - 2700	:	500 - 2700 :
Data runs 0 - 143 using X MSAV( ); X MGET( ) (8 blocks per run)		Data Blocks 0 - 1152 using X MPUT( ); X MGET ( )

SEE APPENDIX E FOR DISCUSSION OF STORAGE ON MASTER TAPES.

APPENDIX A
FOCAL COMMAND SUMMARY

Command	Abbr	Example of Form	Explanation
TYPE	T	TYPE FSQT (AL ↑ 3+FSQT (B))	Evaluates expression, types out and result in current output format.
		TYPE "TEXT STRING"!	Types text. Use ! to generate carriage return line feed.
WRITE	W	WRITE ALL	FOCAL prints the entire indirect program.
		WRITE 1	FOCAL types out all group 1 lines.
		WRITE 1.1	FOCAL prints line 1.1
IF	I	IF (X) 1.2,1.3,1.4;	Where X is identifier or expression.

Control is transferred to the first, second, or third line number if (X) is less than, equal to, or greater than zero respectively. If the semicolon is encountered prematurely then the remainder of the line is executed.

MODIFY	M	MODIFY 1.15	Enables editing of characters on line 1.15

The next character typed becomes the search character. FOCAL will position itself after the search character; then the user may

a. type new text, or
b. form-feed to go to the next occurrence, or
c. bell to change the search character, or
d. rubout to delete backwards, or
e. left arrow to kill backwards, or
f. carriage return to end the line, or
g. line-feed to save the rest of the line.

QUIT	Q	QUIT or * or control-C	Returns control to user.
RETURN	R	RETURN	Terminates DO subroutines
SET	S	SET A = 5/B * SCALE(3)	Substitution statement
ASK	A	ASK ALPHA (I + 2 * J)	FOCAL types a colon for each variable; the user types a value to define each variable.

Command	Abbr	Example of Form	Explanation
COMMENT	C	C - compute area	If a line begins with the letter C, the remainder of the line will be ignored.
CONTINUE	C	C - ignore temporarily	
DO	D	DO 4.14	Execute line 4.14; return
		DO 4	Execute all group 4 lines, return when group is expanded or when a RETURN is encountered.
		DO ALL	Execute entire indirect text as a subroutine.
ERASE	E	ERASE	Erases the symbol table.
		ERASE 2	Erases all group 2 lines.
		ERASE 2.1	Deletes line 2.1.
		ERASE ALL	Deletes all user text.
FOR	F	FOR I = x,y,z; TYPE I	The command string following the semicolon is executed for each value; x,y,z are constants, variables, or expressions. x=initial value of I, y=value added to I until I is greater than z. y is assumed =1 if omitted.
GO	G	GO	Starts indirect program at lowest numbered line number.
GOTO	G	GOTO 3.4	Starts indirect program at line 3.4

C - The Fourteen (14) Functions are

FSQT ( ) - Square Root
FABS ( ) - Absolute Value
FSGN ( ) - Sign Part of the Expression
FITR ( ) - Integer Part of the Expression
FEXP ( ) - Natural Base to the Power
FSIN ( ) and - FCOS ( ), - Trig Functions
FLOG ( ) - Naperian Log

Computed GOTO:

X CALL(N,S) where S is an integer between 1 and 31.

APPENDIX B

ERROR DIAGNOSTICS*

Table B-1
Error Diagnostics of FOCAL, 1969

Location	Code	Meaning
	?00.00	Manual Start given from console.
	?01.00	Interrupt from keyboard via control-C.
0250	?01.40	Illegal step or line number used.
0316	?01.78	Group number is too large.
0340	?01.96	Double periods found in a line number.
0351	?01.:5	Line number is too large.
0362	?01.;4	Group zero is an illegal line number.
0440	?02.32	Nonexistant Group referenced by 'DO'.
0464	?02.52	Nonexistant line referenced by 'DO'.
0517	?02.79	Storage was filled by push-down list.- see below*
0605	?03.05	Nonexistant line used after 'GOTO' or 'IF'.
0634	?03.28	Illegal command used.
1047	?04.34	Left of "=" in error in 'FOR' or 'SET'.
1064	?04.52	Excess right terminators encountered.
1074	?04.60	Illegal terminator in 'FOR' command.
1147	?04.:3	Missing argument in Display command.
1260	?05.48	Bad argument to 'MODIFY'.
1406	?06.06	Illegal use of function or number.
1466	?06.54	Storage is filled by variables.
1626	?07.22	Operator missing in expression or double 'E'.
1646	?07.38	No operator used before parenthesis.
1755	?07.:9	No argument given after function call.
1764	?07.;6	Illegal function name or double operators used.
2057	?08.47	Parenthesis do not match.
2213	?09.11	Bad argument in 'ERASE'.
2551	?10.:5	Storage was filled by text.
2643	?11.35	Input buffer has overflowed.
5042	?20.34	Logarithm of zero requested.
5644	?23.36	Literal number is too large.
6543	?26.99	† Power is too large or negative.
7111	?28.73	Division by zero requested.
7405	?30.05	Imaginary square roots required.
	?31.<7	Illegal character, unavailable command, or unavailable function used.

04:3 — Line too Long

05.:1 — Prog. too Long

See below

*If push down list overflows, try "Type #" to see if unwanted variables are present. Use ERASE, to remove variables, but retain the program.

- When reading/program from paper tape ?11.35 diagnostic can be avoided by use of X STAT(1,980), command, which uses CRT for output listing.

APPENDIX C

SPECIAL FOCAL INPUT-OUTPUT OPERATIONS

for "LICK FOCAL AUG"

The FOCAL system was designed to handle complex arithmetic operations using the typewriter for both input and output. However, in much of our work we need to use additional input-output devices, while keeping the programming convenience afforded by the FOCAL language.

Some changes have been made to the FOCAL system, to allow communication with specially written machine-language programs that take and store data, operate the plotter and disk and look after some awkward data manipulation.

The special operations are handled just like the ordinary FOCAL commands. They are written in the form - (a) SET D = FABC(ARG3, ARG4 --- ARG8) or (b) X ABC(ARG3, --- ---). The arguments ARG3 --- give the numerical values that define the exact details of the operation. Arguments not stated are always taken as zero. The numerical result (if any) of type (a) operations is placed in variable D. Numerical results can have values up to 2^{23} -1, while the arguments usually must not be greater than 4095 ($=2^{12}$ -1). Non-integer arguments are taken as the next lower integer. The final argument of certain commands may be as large as 2^{23}-1.

A summary of the currently available commands is given in the following pages. More detailed explanations of some of the functions are given in later Appendices.

FUNCTION LIST: "LICK FOCAL AUG" SUMMARY

Set D = FITR(N) integer value of N. (D is set equal to integer value of N)
Set D - FLOG(N) log N (D is set equal to log N. to the base e)
Set D = FSIN(N) sine N
Set D = FCOS(N) cosine N
Set D = FEXP(N) exponential e^N
Set D = FSGN(N) sign of N
Set D = FABS(N) absolute value of N
Set D = FSQT(N) square root of N

Set D = FTAK(B,W) get single precision value of word W in disc block B.
Set D = FASK(B,W) get 10 digit floating format variable starting at disc word W, block B. (4 words used) - See X STOR( )

A special command "X" (execute) can be used for functions which need not return a number to FOCAL:

X PUT(B,W,I) Store integer I in disc word W, block B.
X STOR(B,W;V) Store variable V starting at disc word W (Note semicolon)
X DIT(D,T,U) Copy disc block D to block T of tape file 1, tape unit U.
X TAD(D,T,U) Copy block T, tape file 1 to disc block D. " " "

---

‡ X FILE(N) File program N in tape file 2, 3, or 4 for chaining.
‡ X CALL(N) Call program N. X CALL(N,S) - Call program N, start at subroutine S. X CALL(N,128*S+L) Start at line L+1.
‡ X END(Ø) Return to calling program;
Set D = FWHO(Ø) Gives D = S + 4096*N of calling program. (For nested calls)
Storage Allocation on the tape, for chaining programs:

with "FAST" LOADER - BLOCK 160ff

File 2:	N = Ø - 31	Block: 1300-1677
File 3:	N = 32 - 63	1700-2277
File 4:	N = 64 - 95	2300-2677)$_8$

SPECIAL MICROPHOTOMETER COMMANDS - SUMMARY

X ADD(L,M,N,K) Add disk blocks: L + M → N. Add K to each word.
X SUB(L,M,N,K) Subtract disk blocks: L - M → N: add K to each word.
X SHFT(B,N) Move disk Block B to an address N words higher.
X PEN(X,Y) Move chart recorder X steps, then move pen to Y.
X LFT(B,W,N,RS,TH)* Move microphotometer stage left or right, record data, at time intervals of (RS+1)/360 seconds, on disc.

X RIT(B,W,N,RS,TH)* Threshold - start data taking when a data point exceeds TH
Resolution is 2.8*(RS+1) microns
Number of blocks to be recorded
First disc word
First disc block

X UP(B,W,M)* Move up or down M steps of 4.5 microns. Record a reading on disc
X DN(B,W,M)* at each step starting with disk word W, Block B.

*Can be written "Set D = FLFT( )" etc. to put final data reading in D.

‡ Use tape unit 8.

Rapid Plotting of disk data, or functions of disk data.

Set D = FUNC(B,W,K) D becomes a function of disk word W in Block B. Function tables are preset by X SET(A,Z) K/3096 is the fraction used of the second table. Interpolates between the two tables.

X SET(A,Z) Loads two 129 word function tables from blocks A,Z for use of FUNC( ), X PLOT( ), X ICRT( )

*X PLOT(B,L,S,X,N,ND,NF,OF) Applies FUNC conversion to each data point automatically, interpolating between function tables as it plots.

- OF — Offset (1024 full scale)
- NF — First block of data on DISC
- ND — Number of blocks of data on DISC
- N — Number of blocks to be plotted
- X — X steps per data point
- S — Scale = S/16
- L — No. Lines on CRT
- B — First block to be plotted

If L = 0; output is on strip chart.
If ND = 0; direct readings from the disc are plotted, without use of the function tables.

USE X STAT(1,1) to initialize X,Y location
USE X SET(A,Z) to initialize function tables from disc blocks A,Z which represent the calibration at the ends of the data ~~segment~~ on the disc.

*X IFIX(B,0,S,1,N,ND,NF,OF) Used exactly like X PLOT( ), but output replaces ~~faces~~ original data on the disc, instead of going to CRT or recorder.

X MPUT(D,T,N,U) — Copies from Disk to Tape.
TAPE UNIT No. 0-8. (0≡8
X MTAK(D,T,N,U) — Copies from Tape to Disc.

- N — Number of Blocks
- T — First Tape Block (Starting at ~~1200~~ $(500)_8$)
- D — First Disk Block

(Disk Blocks 237-253 are lost)

* Always precede by X STAT(1,1), to preset baseline.

X ICRT(O) exchange X and Y axes for X PLOT( )

X PUTN(B,W,D,N,I) Load disk with linear functions

- I — Data increment for successive words
- N — Word count
- D — First data word content
- W — First disc word address
- B — First disc block address

X STAT(X,Y,S) Send future teletype output to CRT

- S — Letter size
- Y — Y origin (full scale 1023)
- X — X origin (full scale 1023)

X STAT(-1) Send future output to teletype, Initialize Plot( )

X DIS(X,Y) Plot one point on CRT at location X,Y

Special FOCAL Commands for Multi-channel Scanner

*Note that omitted arguments will be taken as zero.

X CLER(B)	Erase data in Buffer B
X SAV(R,B)	Save Buffer B on Disc as Run R
X PULL(R,B)	Recall Run R to Buffer B
X IN(R,B)	Add Run R to Buffer B
X OUT(R,B)	Subtract Run R from Buffer B
S D = FCHAN(N,B)	Set variable D equal to contents of Channel N, in Buffer B.
X EDIT(N,B,K)	Place K in Channel N of Buffer B. $K<10^{24}$

X GRA(S,N,C,M,I,J) CRT Data display

- J — Offset = 512 X J
- I — No. of display cycles (10_M if zero)
- M — Full scale multiplier = 2^M
- C — First channel
- N — No. channels (512 if zero)
- S — Full scale = 1024 X S

X DIVD(O,B)	Normalize buffer B to single precision (4096)

X DIVD(R,B,M,D, L,U) Divides data in Buffer by disc data, or by D

- U — Upper channel used (511 if zero)
- L — Lower channel used
- D — Division if "R = Ø"
- M — Multiplier (1 if zero)
- B — Buffer number (Ø or 1)
- R — Divisor Run No. (single precision data recorder)

X PEN(X,Y)	Move X steps on chart /, then move pen to Y
X SHFT(B,S)	Shift block B by S words

X MOVE(F,N,S,I) Partial channel shift - Buffer 1 to Buffer Ø

- I — Shift per channel changes by I/1000 for each channel
- S — Shift for first channel is S/1000
- N — Number of channels shifted
- F — First channel number

X SWIT(-1)	Erase CRT
X SWIT(Ø,L)	Load lamps L. Lamps are coded 1,2,4,---32.
S D = FSWIT(N,S,Ø,Ø,M)	Read switch N,S to D. Set M = 4095 to read all group N at once. (M = 9 to read switch 1 & 8,weighted, etc.) M = 0 to read only switch N, S.
S D = FSWIT(3,11,X,Y)	Display joystick marker at X,Y. When switch 3,11 is pushed, return 1024*X1 + Y1 where X1, Y1 is final marker location.

X ICRT(0) exchange X and Y axes for X PLOT( )

X PUTN(B,W,D,N,I) Load disc with linear functions
- I — Data increment for successive words
- N — Word count
- D — First data word content
- W — First disc word address
- B — First disc block address

X STAT(X,Y,S) Send future teletype output to CRT
- S — Letter size
- Y — Y origin (full scale 1023)
- X — X origin (full scale 1023)

X STAT(-1) Send future output to teletype

X DIS(X,Y) Plot one point on CRT at location X,Y

X MSAV(B,R,U) Save run on DECtape
- U — Tape unit No. (0-8)

X MGET(B,R,U) Recall run from Dectape
- R — Run No. (Ø-143) [Ø at Block 500]
- B — Buffer (Ø or 1)

Set D = FTOTL(C,B,N) -
- C — Sum channel contents
- B — Number of channels (512 if zero)
- N — Buffer Ø or 1
- D — First channel number

*Set D = FNOIS(N,M,S) Replace data in buffer 1 by data from buffer Ø, if C(1) > C(0) + N
- N — First channel
- M — Number of channels (1024 if zero)
- S — Maximum allowed count difference

*Expects a 1024 channel format, treats lowest 12 bits only, total rejected counts appear in D.

Scanner Memory Commands

X MEMC(T)	Count for T scan cycles (4.096 msec each) Stop counting if T = 0 . Elapsed time is about 4.4 msec per cycle.
Set D = FMEMC(1)	D becomes Zero if scanner count is finished, counting time is unchanged if counting.
X MEME(0)	Erase the data memory (512 word)
X MEMX(1)	Load "X" scan program memory/from Buffer 1 and enable the linear sweep. The X program cycles once per complete scan cycle.
X MEMX(0)	Load "X" scan program memory from Buffer 1 and disable the linear sweep. The X program cycles 8 times per complete scan cycle. (512 word)
X MEMY(0)	Load Y scan program memory/. The Y program cycles once per complete scan cycle.
X MEMR(W)	Read 1024 channels into core memory starting at scanner Channel W. Lower 512 channels to Buffer 1, second 512 to Buffer Ø.
X MEMW(W, N,OR)	Writes N 12 bit words from core buffer 1 into scanner memory. If OR=Ø, low order is loaded; if OR=1, upper 12 bits of memory is loaded. (Useful for hardware checkout)

Data Formating Commands

X FORM(N)	Convert data in core buffer from 1024 channel format into 512 channel segments. Compresses N channels of data into each resultant channel.
X LOOK(X,Y,ST,N,SC,CH)	Allows mapping of image tube face. Plots N vertical lines of varying density, starting at X,Y, with spacing between lines given by ST. SC is counts per dot in each line. CH is the first channel used.
X REVR(W,N)	Reverses the sequence of N channels, starting at channel W.

Description of Arguments for Scanner Commands

B - Buffer number Ø or 1. Buffer Ø uses memory area 14000 to 15777. Buffer 1 uses area 12000 to 13777.

R - Data run number. Each run uses 8 block on the disc. The first disc block number of each run is 8 x R. The first 512 words of any run contain the lower precision and the second 512 words contain the upper precision words of a 512 channel spectrum. (28 runs fill the disc, with blocks 224, 225-free, 226 ff used for program overlay.)

S - CRT display full scale. Each channel content is divided by S before being displayed. (full CRT deflection for 1023 counts if S = 1)e.g. X GRA(10) for full scale 10230.

N - Data channel number. Spectra have channel numbers going from 0 to 511.

K - When replacing the content of a channel in memory, numbers up to $2^{23}-1$ can be used.

T - Counting Time in units of scanner sweep period. (4.096 milliseconds per sweep.) Numbers up to $2^{23}-1$ are acceptable.

U - Tape Unit No. usually either 7 or 8. [Ø and 8 are treated identically by all programs].

Data Scales

Double precision PDP 8 words can hold numbers up to 16,777,215 $(2^{24}-1)$. However, the most significant bit is treated as a minus sign by FOCAL, so that values above 8,388,607 will appear as negative numbers when used by FOCAL'S arithmetic routines.

NOTES ON USE OF DISC AND TAPE COMMANDS

A. If the arguments for disc word and block are both zero the system will always increment the most recent disc address, and use that for the next disc address.

B. The core buffers A and C are used as temporary storage for block by block addition, or alternatively as a function-conversion / tables. ~~This table can be generated for any function y = F(x) by storing values of y for x = 0, 8, 16 ——— 1024 in any disc block. The table is then loaded into core buffer A by function "X SET(N)", (Where N is the disc block number)~~ see Appendix F.

C. Disc Blocks are 129 words long. In a disc address,"Block B, Word W"; W goes from 0 to 128 in one block. An address: block 91, word 131, for example, is exactly the same as block 92, word 2. Both addressing modes could be used interchangeably and the same disc word would be accessed in either case. (W must be less 4096).

D. Restrictions on X CALL(N). X END(N).

These are not recursive functions, so that X END(N) will only recall the last program that used the CALL statement.

The X CALL and X END commands should not be used within a DO loop.

E. Nested program chaining is possible in FOCAL, provided each level of sub-routine explicitly records the return address of the calling program.

Example: PROGRAM NO. 1

```
3.62 X CALL (2,6)
3.66   X CALL (--)
```

PROGRAM NO. 2

```
6.01 SET PG(2) = (FITR(FWHO(0)/4096)
6.02 SET LN(2) = FWHO(0)-PG(2)*4096
6.03 X CALL(7,5); calls some other chained program
6.99 X CAll(PG(2), LN(2)); C- returns to program 1 line 3.66.
```

If statement 6.03 was not used, 6.01 and 6.02 could be deleted and 6.99 would be "X END(0)".

APPENDIX E

Programmer's Note Storage on Master Tapes

The Monitor system on Master tapes stores programs on the tape, starting with the lowest numbered free block (the first few blocks are used up storing the Monitor itself). Data can be stored on the tape by a program called "PUTT" which copies the whole disk onto a selected area of the tape, or by FOCAL, which selectively copies blocks between disk and tape. The tape can hold up to 5 copies of the disk; each copy is called a "file" and files are numbered 0 - 4. The file number merely determines which section of the tape will be used.

FILE NUMBER	TAPE BLOCKS (OCTAL)
0	300 - 675
1	700 - 1275
2	1300 - 1675
3	1700 - 2275
4	2300 - 2675

Blocks 0 - 277 are used only for program storage and cannot be over-written by either PUTT or FOCAL. FOCAL as found on a Master tape can access blocks 300 - 2701 for data storage and access blocks 1300 - 2677 for program storage. Program PUTT will always test the first 20 blocks of any file before writing on it and request confirmation if any non-zero word is found. Thus some protection is given against accidentally overwriting programs with data.

The monitor will use successive blocks of tape for storage as new programs are added. Thus data stored in file zero could be overwritten by a new program added to the tape, and no warning would be given. Data for long term storage should be kept on higher numbered files, or else on a tape on which no new programs will be added.

```
 PIP
*OPT-L

*IN-D0:

FB=0000

NAME  TYPE    BLK
```

Dectape Monitor System
(Unused in most applications)

TAPE STORAGE ALLOCATION

(octal)
Block #

```
8G
GETT.SYS (1) 0006    0
DTAP.SYS (0) 0001
LOAD.SYS (0) 0003
.CD..SYS (0) 0006
COPY.SYS (1) 0006
DISC.SYS (0) 0001      .SAVE --
PUTT.SYS (1) 0006
PIP .SYS (0) 0025
FOCA.SYS (1) 0017
STAR.SYS (0) 0032
STEN SYS (0) 0032
     SYS (1) 0024
     SYS (1) 0037
     SYS (1) 0002    277
D000.SYS (1) 0040    300
D001.SYS (1) 0040
D002.SYS (1) 0040
D003.SYS (1) 0040
D004.SYS (1) 0040
D005.SYS (1) 0040
D006.SYS (1) 0040
D007.SYS (1) 0040    677
D100.SYS (1) 0040    700
D101.SYS (1) 0040
D102.SYS (1) 0040    X DIT
D103.SYS (1) 0040
D104.SYS (1) 0040    X TAD
D105.SYS (1) 0040
D106.SYS (1) 0040
D107.SYS (1) 0040   1277
D200.SYS (1) 0040   1300
D201.SYS (1) 0040
D202.SYS (1) 0040    X FILE (0-31)
D203.SYS (1) 0040
D204.SYS (1) 0040    X CALL
D205.SYS (1) 0040
D206.SYS (1) 0040
D207.SYS (1) 0040   1677
D300.SYS (1) 0040   1700
D301.SYS (1) 0040
D302.SYS (1) 0040    X FILE (32-63)
D303.SYS (1) 0040
D304.SYS (1) 0040    X CALL
D305.SYS (1) 0040
D306.SYS (1) 0040
D307.SYS (1) 0040   2277
D400.SYS (1) 0040   2300
D401.SYS (1) 0040
D402.SYS (1) 0040
D403.SYS (1) 0040    X FILE (64-95)
D404.SYS (1) 0040
D405.SYS (1) 0040    X CALL
D406.SYS (1) 0040
```

CAUTION!!!

PROGRAM "PUTT" CAN WIPE OUT PROGRAMS STORED IN ANY FILE, AND NO ERROR MESSAGE WILL BE GIVEN.

USE PROGRAM "PIP" TO DELETE DUMMY PROGRAMS D000--D407 IF EXTRA SPACE IS NEEDED FOR PROGRAM STORAGE.

..OTHERWISE, NO MONITOR PROGRAMS CAN BE STORED WHERE "PUTT", OR ANY FOCAL COMMAND CAN HURT THEM.

FILE 0

FILE 1

FILE 2

FILE 3

FILE 4

.PUTT

.GETT

Program PIP can be used to determine how many blocks have been taken by the monitor. Type PIP (return) OPT-L (return) IN-DØ: (return). PIP types the number of free blocks, and the names of all stored programs. Restart the monitor by pressing CTRL and typing C.

CAUTION: If many programs are to be stored, study the sheet on TAPE STORAGE ALLOCATION carefully. This indicates the location on the tape of the various files and programs. Since the tape can be used for storage of both programs and data, the user must determine the use of each "file". Possible uses of "files"

a) Programs saved by the Monitor.

b) FOCAL programs saved for chaining by FOCAL'S "X FILE" command.

c) Data transferred from the disc by FOCAL'S "X DIT" command.

d) Scanner runs stored by FOCAL'S "X MSAV" command.

e) Data stored by the program "PUTT"

Initially, the tape is filled with dummy programs D000 -- D407, so that the Monitor's SAVE command can't accidentally write on top of a "file". However, if many programs are to be stored by a tape, some of the dummy programs must be deleted, preferably those in File Ø. After this is done, it is vital that program PUTT should never be used to write File Ø, as it would destroy any programs stored there.

APPENDIX F

Explanation of the "FUNC" Command in FOCAL

Introduction

The command "Set Y = FUNC(B,W)" can be used to calculate "Y" as a function of the content of disc word W, Block B. The function Y = f(x) is first tabulated for the 129 values of Y when X = 0, 8, 16, ---1024. Then values of X between 0 and 1024, stored on the disc, can be rapidly converted to the corresponding value of Y. This table look-up technique is a method of obtaining faster response from FOCAL. It also simplifies the use of functions which do not have a simple mathematical description.

Procedure

Values Yi = f(Xi) are calculated for i = Ø,--128, (where XØ=Ø, X1=8, X2 = 16 --- X129 = 1Ø24) and stored on words Ø to 128 of any disc block NC by successive commands X PUT(NC, i, Yi). Then the command "X SET(NC,NC)" will place that table in the appropriate buffer areas of the computer's core memory. Further commands of the form "SET Y = FUNC(B,W)" will give a value of Y corresponding to the value f(X) where X is the content of disc word W, block B and has a value between 0 and 1024.

Interpolation Between Functions

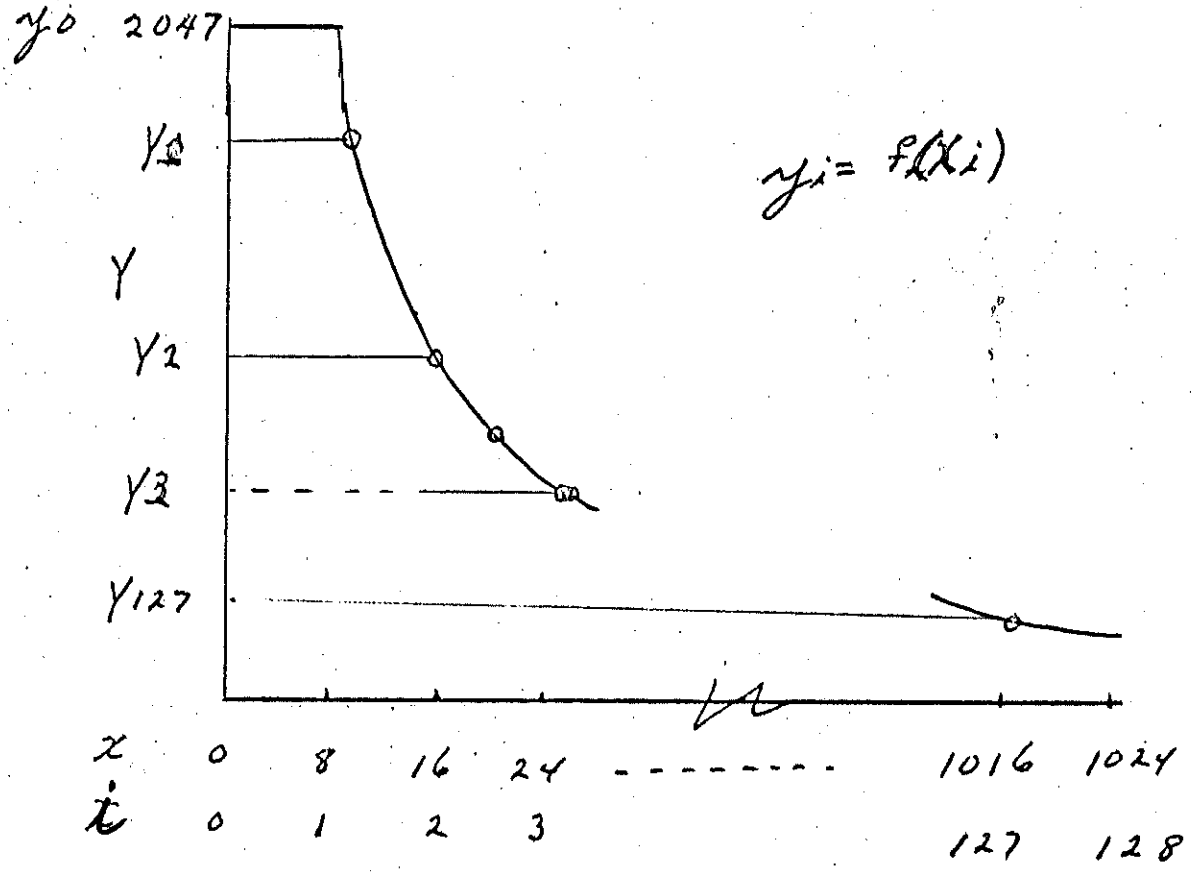
If a function of the form y = M f1(X) + N f2(X) is desired, where M and N change over the region of interest, two tables can be generated and stored in two blocks NB, NC, where f1(X) is in N B Then use the command X SET(NB, NC) to place both tables in core buffers. Now the command SET Y = FUNC(B,W,K) will give a value of y where M = (3096-K)/3096 and N = K/3096. (3096 is the number of words in 24 129 word blocks)

Caution

1. The "FUNC" command uses 2nd order ($Y = A+B\,X+ CX^2$) interpolation between points, so that the result for a rapidly varying function can be

less exact than may be desired.

2. The look-up tables are stored in Buffer "A" and "C" in the computer's memory. Buffer "A" is also used in the commands X ADD() X DN(), X UP(), X LFT(), X RIT() and X SUB(), thus if these commands are used, give the "X SET()" again before using "FUNC()".



y_0 is stored in the first word of the block
y_1 " " " " second "
y_2 etc

For the microphotometer, x corresponds to transmission and y corresponds to intensity

```
01.01 C-DEMONSTRATION OF "FUNC" OPERATION.
01.05 FOR J=0,8,1024;X PUT(5,J/8,100*FSQT(J))
01.10 X SET(5)
01.30 ASK !"X",XX
01.40 X PUT(1,1,XX)
01.50 TYPE "F(X)=",FUNC(1,1)
01.60 GO 1.3
*
 GO

X:2 F(X)=     70
X:102 F(X)=   1009
X:400 F(X)=   2000
X:900 F(X)=   2999
X:901 F(X)=   3001
```

APPENDIX G

Use of the PDP-8 CRT Display

Currently the PDP-8 can store points and characters on the Tektronix type 611 memory oscilloscope. Several FOCAL instructions are available to control writing.

- X SWIT(-1) will erase the CRT
- X DIS(A,B) will place a dot at the x,y co-ordinates A,B. Full scale is 1023.
- X STAT(A,B,S) will direct future teletype output to the CRT, and set the x,y origin to A, B. Print scale is S. If A is negative, or an error diagnostic occurs, output reverts to the teletype.
- X PLOT(B, L, S, X, N, 0, 0, OF) will plot N blocks of 129 words from the disk starting at disk Block B with offset = OF. The Y deflection is proportional to S/L and full scale deflection for 1023 counts is given with S = 16 and L = 1. L lines of 1024 points will be plotted on successively higher segments of the display. X identical points will be plotted side by side for each word taken from the disk.

  Data values must be < 2048 for correct treatment.

If L is zero, the chart recorder is used instead of the oscilloscope.

Example: 1.1 FOR J = Ø,1Ø23; X PUT(B,J,J); creating dummy data

1.3 X STAT(1,1); C-Set CRT baseline

Then: 1.4 X PLOT (B, 1, 16, 8) would draw a diagonal line across the display

OR: 1.4 X PLOT (B, 1Ø, 16, 1Ø, 8) would draw ten lines across the display, each one showing 103 words (1Ø23/1Ø) from the disk.

Special Features

The text writing origin can always be reset while in the CRT character display mode by typing "C&". The use of & in any text string will also reset the origin, and special characters such as "bell" will produce a line feed.

-When text output reaches the bottom of the screen, a new column will start to the right of previously written text.

-X PUTN(B, W, C, N, I) will rapidly load N successive disk words, (starting at Block B, word W with C, C+I, C+2I, C+31 etc.

This is useful when drawing straight lines on the display

APPENDIX H

USE of the X PLOT( ) and X IFIX( ) Commands in FOCAL (Microphotometer only)

The function converter Set D = FUNC (see Appendix F) was designed especially to speed up the conversion of microphotometer transmission data to intensity values, when making strip chart records or CRT displays. In order to achieve higher plotting speeds, an additional command has been developed, which uses the function converter at the machine language level, so that several thousand points can be plotted with a single FOCAL command.

- X PLOT (B, L, S, X, N, ND, NF, OF) will automatically convert and plot up to 24 blocks of 129 data points interpolating between two conversion tables.

e.g.- with a conversion function FB in block NB corresponding to data in block 28, and a conversion function FC in block NC corresponding to data in block 50, data between these two limits, (say 11 blocks starting at block 33) could be plotted using linear combinations of the two functions, by the following commands:

```
X STAT(1,1) ;C- Baseline
X SET(NB, NC)
SET L = 0   ;C -output to chart recorder
X PLOT(33, L, S, X, 11, 50-28, 28, OF)
```

The conversion function used would be fB * K + fC * (1-K) where K has the value (33-28/(50-28) for the first word and increases linearly to (33 + 10 + 128/129 -28)/(50-28) for the last word. The maximum allowed value of ND is 24. If more than 24 blocks are to be plotted, a conversion table should be measured or calculated at the end of each 24 block segment.

The meaning of variables L, S, X, OF is explained on Appendix G.

Conversion of Data on the Disk

The output from the PLOT(---) routine can be directed to the CRT or the strip chart recorder. It can also be redirected to the disk, thus rapidly converting the initial transmission date on the disk to digital intensity data. (This will be useful for computer aided analytical work) To store 24 blocks of disk/data transmission back on the disk as intensity, instead of plotting, use:

X IFIX (B, 0, 16*SK, 1, 24, 24, B, OF)

instead of:

X PLOT(B, 0, 16*SK, X, 24, 24, B, OF)

APPENDIX J

Joystick and Switch Panel

A FOCAL command can read the setting of any switch on the Program Control Panel. It can also display a movable ficucial mark on the 611 Memory Scope and turn on the 6 indicator lamps on the panel. The joystick is used to move the fiducial mark, and the final x, y co-ordinates of the mark can be returned to FOCAL by depressing a push button near the joystick.

SET D = FSWIT(GR, N, X, Y, M)

This command reads switch number N of Group GR.

- In group 1, switches are numbered 1, 4, 7, 10 and can have readings of 0, 1, ---, 7.
- In group 2, switches are numbered 1, 3, 5, 7, 9, 11 and can have readings 0, 1, 2, 3.
- In group 3, switches are numbered 1 through 11 and have readings of 1 or Ø.
- If M is non-zero, it is used as a mask to read several switches of one group simultaneously with the reading of each switch number N multiplied by $2^{(N-1)}$.
- 6 indicator lights are provided, numbered 32, 16, 8, 4, 2, 1.
- X SWIT(0,8) : light lamp 8.
- X SWIT(0,5) : light lamps 4 and 1.
- X SWIT(-1) : erase memory scope

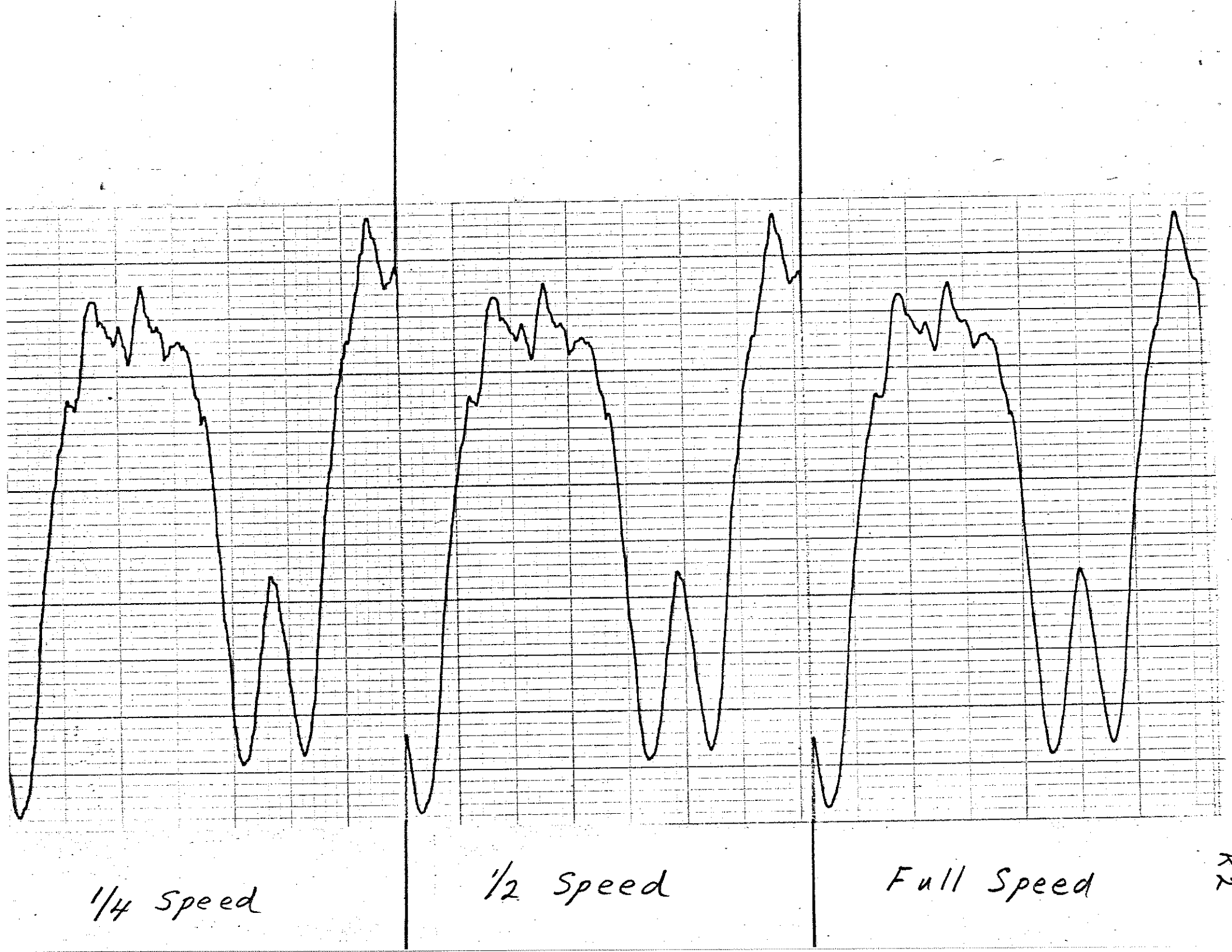
SET D = FSWIT(3, 11, X, Y, 0, Q)

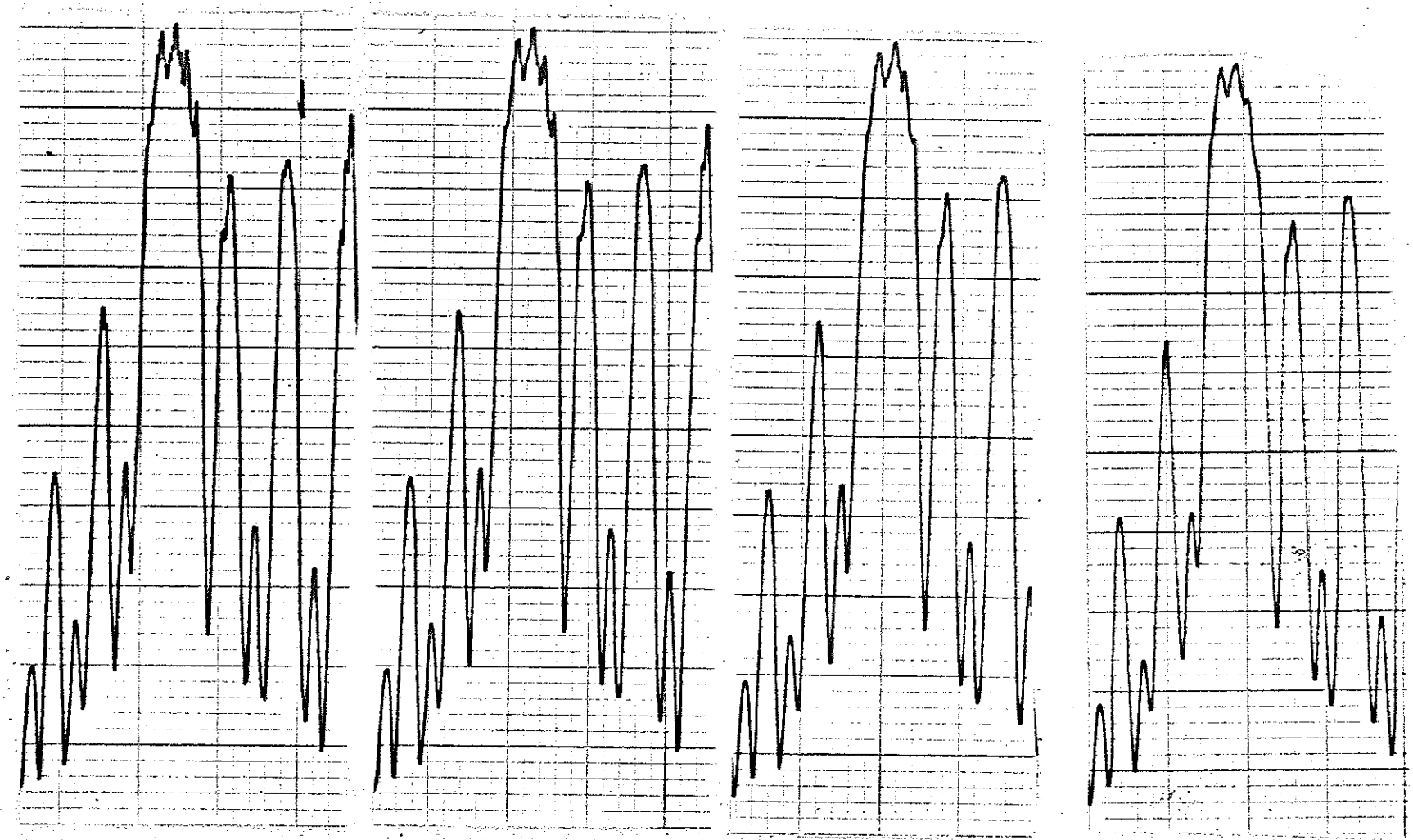
A ficucial mark with initial co-ordinates X, Y is displayed on the CRT (full scale for X and Y is 1023). The mark can be moved by the joystick and when switch "3, 11" reads non-zero, the fiducial mark disappears and D holds

the final Y coordinate plus 1024 times the X co-ordinate. Normally the switch 3, 11 (the push button beside the joystick))is used, but any switch may be selected to terminate the fiducial display and return the final co-ordinates. Normally, to avoid double returns from a single switch motion, the program waits till switch 3, 11 reads Ø before displaying the marker. To get continuous returns with the switch held down, set Q = -1.

Example of Joystick Program

```
1.1  Set X = 400, set Y = 400
1.2  Set D = FWIT(3,11,X,Y)
1.3  Set X = FITR(D/1024); set Y = D-1024*X
1.4  T ! X,Y; GO 1.2
```


1/4 Speed
1/2 Speed
Full Speed



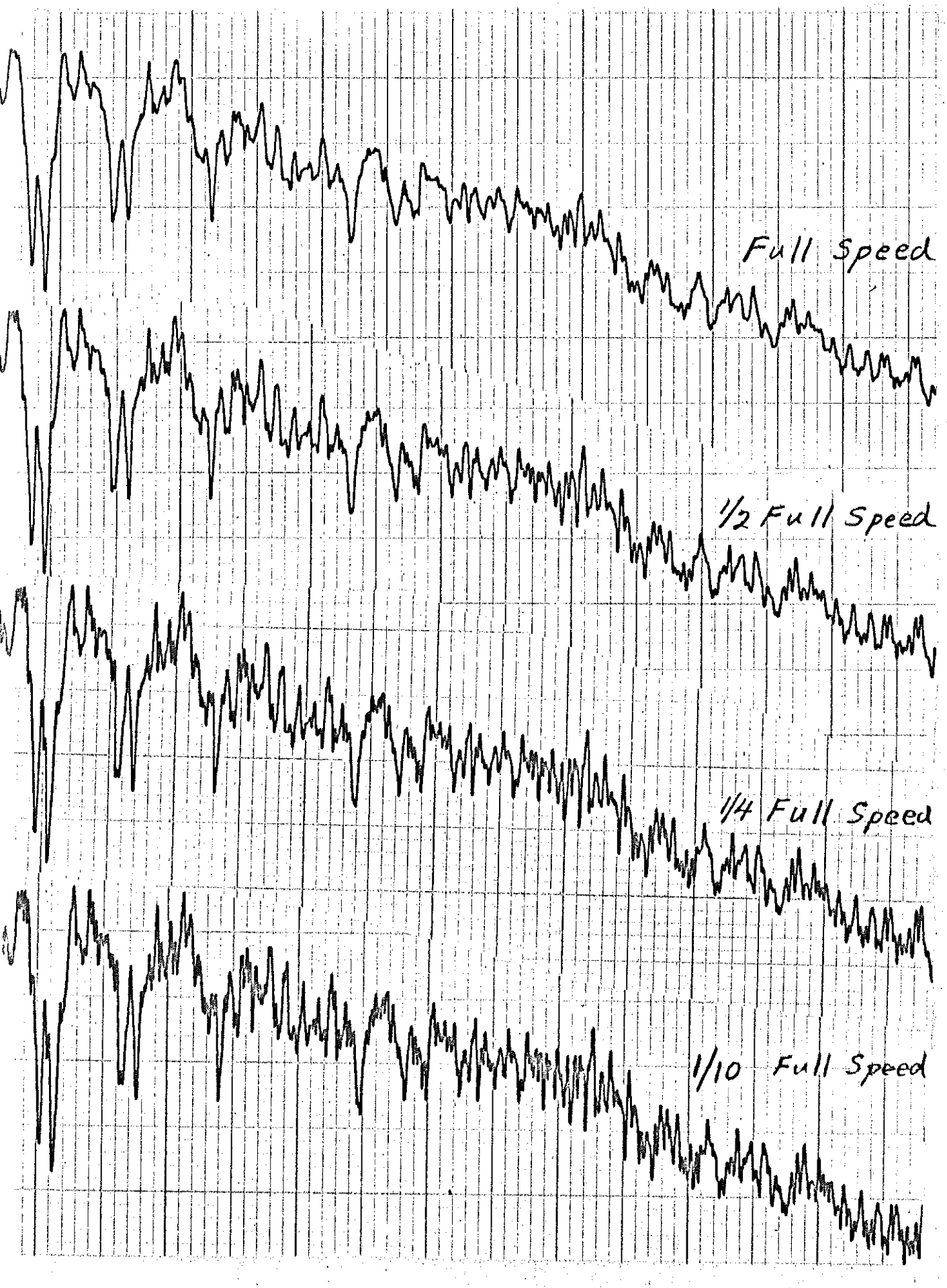
1/10 Speed

1/4 Speed

1/2 Speed

Full Speed

K3


Full Speed
1/2 Full Speed
1/4 Full Speed
1/10 Full Speed

APPENDIX K

Plotter Speeds for the Microphotometer

The microphotometer PDP-8 can drive the Houston plotter at speeds up to 0.5 inches/sec. If a restricted Xscale is used, some loss of fine detail can occur because the pen moves too slowly.

For maximum paper speeds, set the plotter buttons at 20"/min. In order to record more detail, set the plotter speed at 10"/min and request twice the dispersion, or at 5"/min and request four times the dispersion. The resulting chart scales will be the same but plotting time will double or quadruple, and detail of very sharp features will improve.

The attached records show the changes in detail that may be expected as chart speed is changed.

APPENDIX L

USE OF FAST LOADER FOR FOCAL

A). Mount a "FAST LOADER" tape, set "Remote" switch

- Set address 200
  Press LOAD ADD(RESS)
  Press DEP(OSIT)
  Press LOAD ADD(RESS)
  Press START

Tape will spin, stop, then spin again. Teletype types '*' when FOCAL is loaded and ready to go.

B). To copy system onto a ~~new~~ tape

i) An "initial" Focal program can be stored on the system tape:

- Bootstrap the system
- Type in an initial program. Text buffer can be used only up to11777.
- Type L (RETURN); Set write enabled on Tape 8
- In response to the teletype query, type S (store).

ii) The system, with its initial program can be saved on a new tape by mounting the new tape, then typing L (RETURN) and S.

iii) Programs can be "called" from one tape and "filed" on another.

IV) To copy programs 0-25 as well as the FOCAL system to a new tape:

- Bootstrap the old tape on UNIT 8 (write lock)
- Mount new tape on Tape unit 7, (write Enabled)
- Type L, and respond to teletype by typing C.

NOTE: The C and S commands occupy the upper part of the program text buffer. If a long program (past 12000) has been written, or scanner data has loaded buffer 1, the "L" command will merely restart FOCAL.

C). A completely new FOCAL system can be stored on a tape. LOAD "FAST", then load the new system into fields 1, Ø and on the disc. Set tape 8 to write enabled.

Start computer at 2000, Field 1. The new system will be written on the tape in blocks 0 - 131.

D). Program description:

"FAST" occupies core locations 2000-2577 in Field 1.

It stores a one page bootstrap in Block Ø.

It stores Field 1 in blocks 1-37.

It stores Field Ø in blocks 72-131

It stores upper $(6300)_8$ words from the DISC in blocks 40-71

It then recalls Field Ø and restarts FOCAL at location 177

- When the bootstrap button on the PDP 8I is pushed, a short-program is loaded that reads block Ø to the monitor page (Field Ø,7600-7777). This routine then loads Field 1 from tape. The program in Field 1 then uses the FOCAL DECtape and DISC routines (also in Field 1) to load the upper $(6300)_8$ words of the DISC and finally Field Ø from tape. Finally, it starts FOCAL at location 177, Field Ø.

Scanner data is stored from Block $(500)_8$ upwards (Previously 300). "TAD" and "DIT" refer to tape Block $(700)_8$ as Block Ø . (as always.) "CALL" and "FILE" store programs starting at Block $(160)_8$. (Previously $(1300)_8$) "MPUT" and "MTAK" store disk data starting at tape block $(500)_8$.

APPENDIX M

Disk Overlay System

Modifications to FOCAL allow for up to 64 special instructions of the form "X Code(ARG3,--ARG10)." Each such instruction can call a specially written machine language program to perform some required function.

The core memory space in the PDP 8I is limited, and when used with the scanner, 25% of the memory is required for data storage. After essential system functions such as disk and dectape access are provided, only 512 words remain for machine language routines, and 800 words for FOCAL text.

The text area has been expanded by use of chaining and automatic subroutine calling from Dectape.

The machine language area has been expanded by an overlay system using the DF 32 Disk.

Overlay System

Machine language programs are assembled, and then stored on the Dectape in a table called "SET1". SET1 is placed on the last 3.5 K words of the disk before starting to work. (by the bootstrap routine).

A table in FOCAL gives the location on the disk of each machine language program, and when one is requested by a FOCAL command, it is transferred from the disk into core memory, before running.

Generally, this overlay procedure does not cost much in execution time, but certain sequences may be unexpectedly slow: For example, the command SET D = FCHAN(N) uses overlay No. 1, while the CRT lettering routine uses overlay No. 2. Thus a sequence:

1.1 X STAT(1,1000,1); FOR J = 0,499; T! FCHAN(J) would have to get two programs from the disk for each channel printed on the CRT, which would limit the printing speed. Higher speed would be obtained by:

```
1.1 X STAT(1,1000,1); For J = 0,50,450;DO 2
2.1 For K = 0,49; SET D(K) = FCHAN(J+K)
2.2 For K = 0,49; T! D(K)
```

Since the disk would only be used 20 times instead of 1000 times.

PROGRAM STORAGE ALLOCATIONS

Permanent	FPUT, FTAK, FSTOR, FASK, FDIT, FTAD, FWHO.
Overlay 1	GRA, EDIT, SAV, PULL, CHAN, SHFT, MSAV, MGET, CLER, IN, OUT. FTOTL, NOIS.
Overlay 2	STAT, CRT Lettering, STOR, FASK
Overlay 3	DIVD, MOVE, SWIT
Overlay 4	PUTN, PLOT, ICRT, DIS, PEN, FILE, CALL, END
Overlay 5	Scanner memory control
Overlay 6	-

The overlay system commandeers the last 3.5 K words of the disk, so programs attempting to access beyond Block 225 or RUN 27 will cause a diagnostic "DISK END".

PROGRAMMER'S NOTE - DISK OVERLAY PDP 8/I

The Disk Overlay System loads one of several machine language programs into field 1 core locations 6042-6777 when a FOCAL command requires a program not already in core. Dispatch table entries less than 177 are recognized as program numbers and the referenced program is read from the disk. (Whenever a program is in core, the corresponding Dispatch table location holds an address greater than 6042)

System Building

A. Initialize: Call "FOCAL", load "GODO", load "ENTR", Call INIT;
("FOCAL" is the Field 1 part of Lick FOCAL)

SAVE SET^1 500-6777; (saves entries to permanent programs in "FOCAL")

SAVE XFOC 10000-1177, 6000, 7000-7577; 1000

B. To add a new program (machine language) to XFOC, using the Disk Monitor:

Call XFOC

Load all programs for one overlay image

Call SET1

Call STOR

STOR first removes all previous references to the new overlay program number. Then, for each new entry found in the XFOC dispatch table, it places a reference to the program number in corresponding words of the dispatch table images in "SET^1". Then it copies the new entries into the single dispatch table image in "SET^1" that corresponds to the new program number. The new entries in the "XFOC" dispatch table are replaced by references to the new program number.

Finally the new program is copied from locations 6042-6777 to the SET1 image corresponding to the new program's number.

In case a new program uses a dispatch table location already taken by a program of different number, a diagnostic will be typed giving the location in "SET1" that is to be changed, as well as the new and old contents.

When done, "STOR" requests that the newly revised version of "SET1" and "XFOC" be saved.

Finally, "PIP" is used to transfer the new "SET1" and "XFOC" to the Master system tape. When used in a FOCAL system, "SET1" is loaded onto the disk by "XFOC" , only if the tape monitor is in core.

For general use, "FAST" tapes are prepared containing the FOCAL system It is advisable to run FOCAL from a "FAST" tape to avoid the possibility of a FOCAL command overwriting part of a system tape.

Programmer's Note

Procedure to Prepare and Add Machine Language Subroutines

to LICK FOCAL (Scanner Version)

A) Without DISK overlay. (Only Basic FOCAL commands plus PUT, FTAK, ~~STOR, FASK,~~ DIT, TAD will be available.)

- Program can use Field 1 locations 2000-6777 as well as 10,---17, 100-110. Note however that normally, data buffers occupy 2000-5777
- Select name code and entry point for new routine.

The command for such a program would be:

Set D = FNAME(ARG3, ARG4,---ARG10) or X NAME( ) ARG3, ARG4, ---ARG10)

Proceed the Coding for your Program by:

```
*KB1+N     N=12---77
BEGN

*FNKB1+N
CODE FOR "NAME"  see Note I

*GETPRX
BEGØ               (DISCONNECTS THE OVERLAY SYSTEM)

*6ØØØ
BEGØ,Ø
   CDF!CIF         (KILLS ANY ILLEGAL OVERLAY ATTEMPT)
   JMP I .+1
   2ØØ  (RESTART FOCAL)

BEGN,Ø
-
-
-
YOUR PROGRAM

-
-
TAD RESUL1         /LOW ORDER 12 BITS OF RESULT
DCA ARG2
TAD RESUL2         /HIGH ORDER 11 BITS AND SIGN
DCA ARG1
JMP I BEGN
$
```

When assembling the program, use PALP

```
OUT:  S:NAME
 IN:  S:CONØ, S:NAME
```

CONØ contains pointers to page Ø, field 1: ARG1,---ARG10, KB1, FNKB1, etc., as well as entries to teletype, DISC and DECtape handlers. Several numerical constants are also defined.

To add the finished program to FOCAL DECtape, first load:

FOCAL (XFOC) then load, "NAME"

SAVE NFOC! 10000-1177, 2000-7577; 1000

NFOC now includes your special program.

To start the program: .NFOC (Ignore the message typed here)
.START

B. WITH DISC OVERLAY SYSTEM: (recommended)

ASSEMBLE THE PROGRAM AS BEFORE, BUT PRECEED THE PROGRAM BY:

```
*KB1+N            N =12--  77.
BEGN

*FNKB1+N
XXXX              OCTAL NUMBER REPRESENTING COMMAND CODE (See Note I)

*6Ø42
-BEGN, 0
-
YOUR MACHINE LANGUAGE PROGRAM HERE
-
- JUMP I BEGN
$
```

WHEN LOADING INTO THE FOCAL SYSTEM:

```
.XFOC
.LOAD
IN:S:"NAME"  (LOAD YOUR MACHINE LANGUAGE PROGRAM)

.SET1
.STOR
PROGRAM NØ:  Choose a program No. whose current contents are not needed.

SAVE SET1 -----ETC.
.SAVE SET1! 500-6777;
.SAVE XFOC! 1ØØØØ-1177,6ØØØ-7577;1ØØØ
```

NOW USE "PIP" TO TRANSFER PROGRAM XFOC AND SET1 TO DECTAPE.

NOTES:

I. A "hash" code technique is used to allow FOCAL to recognize function names. ASCII codes for each successive character are added, with successive shifts of one octal digit. Only the lower 11 bits are retained.

For example, the code for "NAME" would be the sum of ASCII codes for N A M E.

$$[N*(1000)_8 + A*(100)_8 + M*(10)_8 + E]$$

The lower 11 bits form a numberical code for the name. The code for "NAME" would be $(1555)_8$. Any one-to-four letter code can be used for a command code. Since only 2047 codes are possible to cover $(26)^4$ possible names, care should be taken to avoid duplicate codes.

FOCAL matches the position of the code in one list starting at FNKB1, with the position of an entry point to the desired subroutine in a second list starting at KB1.

II. The ASC11 language source programs for the Lick Focal system are stored as individual short listings using the standard DF 32 Disc Monitor.

The image of the disc is saved on a Dectape, and is loaded back onto the disc in order to add or change instructions in Lick Focal.

Adding Programs to FOCAL DISK OVERLAY

```
?(DISC Monitor)
.XFOC
.LOAD
*IN-S:SHIF,S:EDIT,S:
```

OPERATOR'S TYPING UNDERLIN

```
.XFOC
.LOAD
*IN-S:SHIF,S:EDIR,S:STAP↙
*
*
*
*OPT-1
ST=↙
↑↑↑↑
.LOAD↙
*IN-S:CLER,S:SCAN,S:FCRT↙
*
*
*
*OPT-1
ST=↙
↑↑↑↑
.LOAD
*IN-S:ADSC,S:TOTL,S:NOIS
*
*
*
*OPT-1
ST=↙
↑↑↑↑
.SET1
.STOR
PROG NO.(1--6):1

SAVE SET1!500-6777!
...XFOC!10000-1177,6000,7000-7577!1000
.SAVE SET1!500-6777!↙
.PUTT
SET TAPE 8 TO WRITE ENABLED.
FILE NO.(0-4):4
 FILE 4 FULL.TYPE Y TO REUSE IT :Y
DONE!
.PIP
*OPT-S

*OUT-D0:SET1
*
*IN-S:SET1
*↑
*OPT-
.DTAP
.FAST
.SET1
.XFOC
.STEN
*1.01 C-SEPT.27/71.
*
DONE!
*
```

Press CTRL-P for each ↑
Press Continue each time CPU halts.

Programs previously assembled using the DISK MONITOR.

XFOC unchanged this time. Normally .SAVE XFOC!----

Normally transfer new version of XFOC as well.

(CTRL C) — Get Dectape Monitor

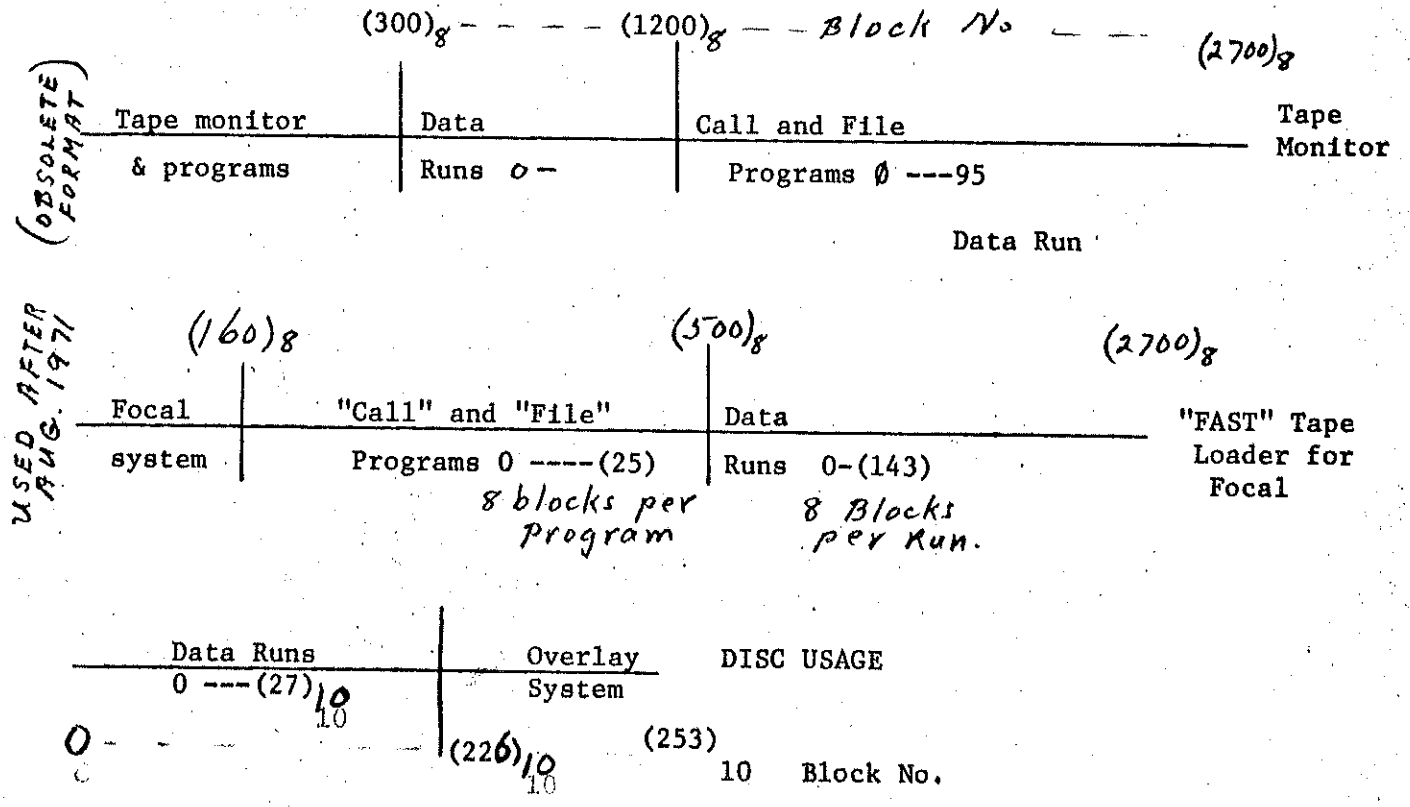
Now start manually at 12000 with a useable tape on unit 8. Write Enabled.

New System ready to use!

DISC and TAPE UTILIZATION

The disc and single dectape have limited storage capability. Lick FOCAL can use all of the disc when running, and has access to Dectape blocks above $(300)_8$. Thus the system can be safely operated and run by the dectape monitor, but not by the disc monitor. It is convenient however to assemble the machine language subroutines for new FOCAL commands using the disc monitor.

When "XFOC" is loaded by the tape monitor, it expects to find "SET1" in core, and copies it onto the last 3K of the disc, for later use of the overlay system. However, when XFOC is loaded into core by the disc monitor (necessary when adding or changing commands); it discovers that the tape monitor is absent and doesn't alter the disc content. In this way the disc monitor can be safely used in preparation of the FOCAL system, even though it cannot safely run the Lick FOCAL system.



APPENDIX P

Detailed Command Descriptions

1. X DIVD(RN,B,M,D,L,U) - Fast integer division.
   - Divide Buffer B by RUN RN on the DISC. (Only the low order part of RUN RN is used, so RN should be normalized so that no channel contains more than 4095)
   - Multiplies each channel content by M to maintain precision.
   - Operates from channels L to U, from channel L to 511 if U is zero or omitted, or on all channels if L and U are zero or omitted.
   - X DIVD (0,B) will divide contents of data Buffer B so that no channel contains more than 4095 counts.
   - X DIVD(0,B,M,D,L,U) will divide by D instead of the disc contents.
2. X MOVE(N,C,K,I) - Fast partial-channel shifter.
   - Moves channels N through N+C by a fraction of a channel. Shift of channel N is K/1000. Successive channels are shifted by (K+I)1000, (K+2I)1000 up to K+(C*I)/1000 for channel N+C. Shifting is done by replacing contents of channel j: "c(j)" by SH*C(j+i)/1000 + (1000-SH)* C(j)/1000 where i is +1 for negative shift, and -1 for positive shift, SH is the absolute value of the shift $K+j_*I$

To Be Continued!