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PROGRESS REPORT ON THE SYSTEM FOR
COMPUTER-OPERATED RADIATION EVALUATION

by

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ABSTRACT

This report discusses some system and software design criteria for the development of a system for computer-operated radiation evaluation. Either scintillation or a solid-state radiation detector may be used. A supervisory program is discussed which services an analog-to-digital converter in real time. This program includes keyboard control of all operational functions such as clear data storage, data taking, display, integration, spectrum analysis, and count rate. Examples of application programs illustrate on-line control and analysis.

I. INTRODUCTION

Fuel assay is necessary for physical control of special materials. The past development in fuel-assay work with a gamma-ray counting technique has made it possible to calculate the uranium-235 loading of reactor fuels.¹ This technique consists of scanning fuel plates with a scintillation detector and obtaining a total count of the 184-keV energy gammas that are emitted by uranium-235. After special calibration, these data are used to calculate the weight of uranium-235 and its associated degree of uncertainty. This analysis is discussed in Section 7 of the chapter on Scintillation Spectrometry in Ref. 2.

Accurate error analysis could not be performed because of the complexity of a precise error analysis for this problem and the time needed for the large volume of fuel inspections required. In the past, graphical techniques were employed. For the study of fuel homogeneity, it is desirable to collect data of approximately 125 unit areas of a fuel element and analyze the data to give uranium weight per unit area.

The solution of these problems requires the speed, precision, and accuracy for large amounts of data that can be met by an on-line computer. This on-line computer system, which we call System for Computer Operated Radiation Evaluation (SCORE), has been built. An on-line computer

provides a data-gathering and -analyzing device and eliminates the long time delay between the completion of a test and the receipt of the result. In addition, an on-line computer provides constant feedback as to the validity of data as they are collected. This allows the operator to take immediate corrective action in case of malfunction, thus eliminating the loss of valuable time.

This paper is a report of the progress in software programming used in SCORE. The information included is helpful to the operator using the analyzer, which is now operational (see the example experiment in Chapter III), and to the programmer making revisions (see Appendix A).

II. SYSTEM DESIGN

The overall system design for an on-line computer is governed by the data format and data rates. SCORE is principally for single-parameter gamma spectrometry using scintillation² or solid-state detectors.^{3,4} Similar systems have been developed.^{5,6} For the analog-to-digital conversion, a Nuclear Data 161F ADC⁷ was interfaced to the computer. The DEC⁸ interface was modified to allow computer control of the ADC interrupt and to use Nuclear Data-502 Spectrum Stabilizer. This converter, with a conversion rate of 16 MHz, might process a typical, random arriving pulse in 25 μ sec. With these data rates, a random-access, high-speed general-purpose machine with program interrupt will meet the system requirements.⁹ The computer used in SCORE is a DEC PDP-8 with an extended arithmetic element (EAE). This machine has 4096 twelve-bit words of memory. The memory cycle time is 1.5 μ sec. The input-output devices include keyboard-printer and tape reader-punch, high-speed tape reader, oscilloscope display, and light pen. A system photograph and a block diagram are shown in Figs. 1 and 2.

Fig. 1
System for Computer-operated
Radiation Evaluation

Fig. 2. System Block Diagram

Some helpful articles on selecting a computer are contained in Control Engineering.^{10,11}

III. SOFTWARE DESIGN

To facilitate on-line computation, we used a modified DEC floating-point system, Digital 8-5D-S with EAE. This package includes the output controller and extended functions. The supervisory program's operational functions (for example, data taking, display, print, punch, spectrum analysis, and count rate) are written

as independent subroutines to assist in the writing of application programs. The program notes and listing are contained in the Appendixes. The Variable Multichannel Program (VAMP) may have two application programs in memory. One, the keyboard control, is an integral part of VAMP and allows operator control of operational functions and system parameters. The other application program would be written in Macro-8 symbolic language for a specific experiment. This program would occupy core space adjacent to VAMP at the expense of the space for data channels. Figure 3 is a PDP-8 core map. Martin¹² has written a useful text on this type of programming.

A. Application Programs

1. Keyboard Control

The VAMP program is read into the PDP-8 using the binary loader, Digital 8-2-U, with starting address 7777. Library programs are also read in, using the binary loader. To start the keyboard control mode directly, load address 3200, and then depress the START button.

Fig. 3. PDP-8 Core Map

The computer now awaits a command, all of which are a combination of two letters. Upon completion of a command, a bell rings and the computer awaits another command. Incorrect commands are ignored, and a "?" is typed. The commands are (where xxxx stands for the input number, and - stands for any nonnumerical terminating character, such as a space):

<u>Command</u>	<u>Operation</u>
----------------	------------------

FS xxxx-	The Full-Scale number of channels governing the operations discussed below, that is, AN, DS, IN, CD, CH, and PN directly, and ED indirectly. This number must be a positive even integer and no larger than 768 (the maximum number of channels with no library programs).
----------	--

- LS xxxx - Lower and Higher Settings for the digital discriminator used in data collection (ED). This window must not exceed 768 channels, but can be as small as two channels.
- HS xxxx -
- CK xxxx - Live-time Clock for ED in units of minutes or tens of minutes as set on the Nuclear Data clock. The maximum number of units is 419.300.
- CD - Clear Data, in all channels given by FS, to zero.
- CH - Clear data in the lower Half of channels given by FS.
- ED - Enable Data taking with live display. The light pen is set for point inquiry, and the running-time clock is reset. Data are collected until (1) the preset time CK is reached, or (2) the command ST is given. The data in the channel equal to the number entered as LS are stored in the first word of data storage. No data outside the digital window formed by LS and HS are stored. The live display is controlled in a manner similar to that in DS.
- ST - Stop data collection. Return to keyboard control.
- CN - Continue is to be used after ST. This command continues data collection without resetting the running-time clock.
- RT - The Running Time is printed.
- TT - The Total Time is printed (i.e., the number given in CK).
- DS - Display the number of channels given by FS. Display is controlled by means of the computer switch register, shown in Fig. 4.

Fig. 4. Computer Console Showing Switch Register

The octal combination of Bits 8-11 control the scaling of the count data as follows:

<u>Bits 8-11, Octal Value</u>	<u>Number of Counts at Full Scale</u>	<u>Number of Counts at Zero</u>
0	2,095,104	2,047
1	1,047,552	1,023
2	524,288	511
3	261,888	255
4	130,944	127
5	65,472	63
6	32,736	31
7	16,368	15
10	8,184	7
11	4,092	3
12	2,046	1
13	1,024	0
14	512	0
15	256	0
16	128	0
17	64	0

Bits 0-2 control the display function as follows:

Bits 0-2,
Octal Value Function

0 Normal display; light pen ignored (Fig. 5)

Fig. 5. Normal Data Display with the Memory Used in Halves

- 1 Enter expansion and integration. The light pen is used to point out the lower and upper limits of expansion (shown in Fig. 6), then the lower and upper limits of integration (shown in Fig. 7). The limits of integration are printed together with the inclusive sum or integration. The display remains expanded with vertical markers through the points last indicated. Another integration may be performed or the display may be switched to normal (0), to command (6 or 7), or to point inquiry (2). NOTE: Integration with Bit 3 = 0 sets up CZ; integration with Bit 3 = 1 sets up CO.

Fig. 6
Data Expansion

Fig. 7
Data Integration

- 2 or 3 Enter expand and point inquiry. The light pen is used to point out the lower and upper limits of expansion (shown in Fig. 6); then the point of interest (shown in Fig. 8). The channel and its contents are printed. The display remains expanded with a vertical marker through the point of inquiry. Another inquiry may be performed or the display switched to normal (0), to command (6 or 7), or to integration (1).

Fig. 8
Data-point Inquiry

- 4 or 5 The data halves (as given by FS) are superimposed (as shown in Fig. 9), and the light pen may be used for point inquiry. There is no expansion.

Fig. 9
Data Superimposition

- 6 or 7 Return to keyboard control.

- IN ————— INterchange the upper and lower halves of data as determined by FS.
- AN ± xxxx- ———— ANalyze the spectrum by multiplying each channel in the upper half of FS by the factor following the AN command, and add the result to each corresponding channel in the lower half. The upper half is unchanged.
- CO ————— Count rate One is computed using the data zone last pointed out with the light pen in data integration (Octal Value 1) with Bit 3 = 1. The count rate is printed.
- CZ ————— Count rate Zero is computed using the data zone last pointed out with the light pen in display (Octal Value 1) integration with Bit 3 = 0. The count rate is printed.
- LC xxxx- ———— Lower and Higher Channels for the print command PT.
 HC xxxx- ———— LC must be greater than or equal to LS and less than HC.
- PT ————— PrinT the run time and data, starting with the channel given by LC and ending with HC.
- PN ————— PuNch out in binary format the running-time clock, the total-time clock, and the low half of data (1/2 FS) if Bit 0 = 1 or all the data (FS) if Bit 0 = 0. Set Bit 0 before giving the command. The output data tape can be read in using the binary loader.
- C; ————— Comment routine permits the user to comment throughout the program. VAMP itself ignores these comments, and they are output as received. Return to command follows an "!. "

At present there is a small library of additional routines that are read in over VAMP via the binary loader and called by keyboard control. They are as follows:

<u>Command</u>	<u>Operation</u>
----------------	------------------

ND xxxx- ————	IN Data is a routine for reading data tapes in binary-coded decimal (BCD) format from other analyzers. Enter the number of channels to be read in after the command (max 718).
---------------	--

SH ± xxxx- ————	The SHift routine permits the adjustment for zero-energy shift of a spectrum. This routine shifts a block of channels xxxx number of channels - (left) or + (right).
-----------------	--

For shifts in either direction, zeros are shifted into vacated channels and whatever is shifted out of the block is lost. A block of channels is defined by Channels Size CS xxxx-, which must be entered before calling SH. The number for CS is the difference between the leftmost, initial channel number and the last channel number on the right to be shifted.

- SU ————— SUBtract routine subtracts incoming counts from the stored data. Parameters for SU are the same as those for ED.
- CE ————— CodE (see Section 2 below)
- TP ————— The TaPe routine allows a punched paper-tape program of VAMP keyboard commands to be read from the high-speed reader. For formatting purposes, TP ignores blank tape, carriage return-line feed combinations, rubouts, and leader trailer. All regular and library commands may be programmed in the same manner as they would be entered via the keyboard. Commands with input (e.g., FS) may be terminated by any nonnumerical character except carriage return and line feed. TP completely ignores the keyboard. When a program tape has ended (as signified by a "\$" following the last command), TP returns to keyboard control.

2. Program Code

An example of an application program is CODE (Computer Operated Data Evaluation). CODE is called by keyboard control, which is also used to initialize the system parameters. CODE counts a reference source, then a given number of unknowns (maximum 26), repeating each unknown a given number of times (maximum 2047). Following the first count of an unknown, its sample number, with up to five numbers or letters, may be typed in and must terminate with a carriage return. The computer waits for a carriage return after each sample count. This indicates that the sample is positioned. When all unknowns are counted, the reference source is counted again. Then the count-rate data array is averaged and normalized to the reference source count rate. This data array is then processed by a linear transformation equation. After the results and corresponding sample numbers are printed, the cycle begins again with another unknown.

The following data-taking subroutine illustrates the use of the VAMP program:

```

COUNTS, 0
JMS I LCDATA / Clear data
JMS I LNABLE / Take data with live display
JMS I LCZ / Integrate Zone 0 last
TAD SP / Indicated with light pen
JMS I LPRT1 / Print space
JMP I COUNTS

SP, 240

```

The wait subroutine, which waits for a carriage return, could be modified to work with an automatic sample positioner interfaced to the computer. The Quality Evaluation Section of the Special Materials and Services Division is now building such a computer-controlled positioner.

B. Example Experiment

This example experiment illustrates the use of the VAMP program. In the experiment, the memory is used in halves, with 384 channels in each half. A combined Co^{60} and Na^{22} spectrum is to be collected in one half, and a Na^{22} spectrum in the other half. Then the Na^{22} spectrum is subtracted from the combined spectrum. Since we are concerned here mainly with the use of the software, the setup of the detector, amplifiers, and ADC is not explained. However, the control of the VAMP program via the teletype keyboard and the switch register (Fig. 4) will be explained step by step.

1. Program Read-in

- a. Place the VAMP tape in the high-speed reader.
- b. Set 7777 in the switch register, and press the LOAD ADDRESS button.
- c. Depress Bit 0, and press the START button.
- d. After the VAMP tape stops, place the SUBTRACT tape in the high-speed reader, and repeat steps b and c.
- e. Turn the teletype switch to the line position.
- f. Set 3200 in the switch register, and press the LOAD ADDRESS and then the START buttons.

The teletype should ring a bell and is now waiting for a command.

2. Data-collecting Parameters and Time Setup

In the experiment, the 1.17-MeV Co^{60} peak fell in about channel 2250; hence the first channel in the digital window (LS) was set to 2200.

The live-data collecting time was to be 10 min (clock switch on ADC set to MIN). The following commands were given via the teletype keyboard to set up these parameters (—indicates space that operator types):

```

FS— 768 —   : We wish to use the maximum number of
               channels.
LS—2200 —   : First channel in digital window.
HS—2583 —   : HS = LS + 1/2 FS - 1 for memory used in
               halves.
               : HS = LS + FS - 1 for normal memory.
CK — 10—    : Clock set for 10 live time minutes.

```

3. Data Collection

The following commands were given to start data collection:

```

CD           : Clears all previously collected data.
ED           : Starts data collection. The Co60 and Na22
               sources were previously positioned under
               the detector.

```

At this point the incoming data are displayed on the scope, and the light pen may be used to inquire where the peaks are falling. (To see the incoming counts, we may need to adjust the scaling Bits 8-11. If Bits 8-11 are set to octal value 17 and no data are observed, then the ADC and amplifier may need adjustment so the peaks will fall in the digital window between HS and LS, or the digital window may be moved to where the peaks are falling.) For example, we point the light pen at the incoming Na²² peak and open the shutter. The following was printed on the teletype:

```

2426    1142 : Channel number and number of counts.

```

If we wish to know how long data have been collecting, we give the following commands:

```

ST           : Stops collecting data.
RT    9.261  : Live time elapsed in minutes.
CN           : Continues data collection.

```

When the preset live time has elapsed, a bell rings, the ION light on the computer console goes out, and the display stops. We now remove the sources and subtract the background by giving the SU command.

After the bell rings, indicating that the background has been subtracted, we interchange the data regions, collect the Na²² spectrum and subtract background by giving the following commands:

IN : Interchanges data halves.
 ED : Collects data. The Na^{22} source is positioned under the detector before the command is given.
 SU : The Na^{22} source is removed before giving the command to subtract the background.

4. Display and Subtraction

The following commands were given:

IN : Interchange data halves.
 DS : Display.

Then Bits 8-11 of the switch register were adjusted giving the display shown in Fig. 5. This is called a normal data display.

With Bits 0-2 of the switch register set to 2, the light pen points out a point to the left and then a point to the right of the Na^{22} peak. The display then expands, and with an adjustment of Bits 8-11, the display appears as in Fig. 6. This is called an expanded display. The light pen may point out any point in the expanded display, and the teletype will print the channel number and the number of counts in that channel. When we point out the peak channel, the teletype prints

2426 1836

and the marker moves to the channel on the display that was pointed out. The display appears as in Fig. 8. When Bits 0-2 are set to 0, the display returns to normal.

We now set Bits 0-2 to 1. Again points to the left and to the right of the Na^{22} peak are pointed out, and the display expands. Now, if we point out a point to the left and a point to the right of the Na^{22} peak, then something like the following would be printed:

2412 2438 : 16,037 is the sum of the counts in the
 0.1603699E+05 channels between and including channels 2412
 and 2438.

The display appears as in Fig. 8. When Bits 0-2 are set to 0, we return to normal display. Normal display is ended by setting Bits 0-2 to 6. A bell rings, indicating that the teletype is waiting for a command.

We decided to multiply the counts in the right half by 0.95 before subtraction from the left half. We gave the following commands:

AN —.95 — : Multiply right half by .95, and subtract
product from left half.
DS : Display.

The subtraction was done, and the resulting spectrum is shown in Fig. 10. If Bits 0-2 are set to 4, the data halves are superimposed as shown in Fig. 9. The small peak where the Na^{22} peak was subtracted out is due to a slight gain shift. To discontinue the display, we set Bits 0-2 to 6.

Fig. 10. Spectrum Subtraction

5. Punch and Print

To save the Na^{22} spectrum, we give the command

IN : Interchange the data halves

to interchange the data, raise Bit 0, so that only the Na^{22} data are saved, turn on the punch, and give the command

PN : Punch.

The leader and trailer are automatically generated.

We also wish to print the channels in the Na^{22} peak. To do this, we first set up the channel numbers to be printed:

LC-2410 — : First channel to be printed.
HC-2439 — : Last channel to be printed.

Then we give the command

```
PT
10.000 2410
 57      59   84   75   95  141  165  229  268 345
532      675 976 1272 1561 1804 1849 1659 1490 996
707      384 225  110   70   36   27   15   14   6
2440
```

The first line contains the clock and the first channel number, the following three lines contain the data, and the last line has the last channel number printed.

This concludes the experiment.

APPENDIX A

Program Notes

1. Introduction

The VAMP program is written in the modular form of subroutines. This is done to facilitate modifications and the writing of application programs. The present version occupies octal locations 1-177 and 3200-7577; data and application programs, if any, are stored in locations 200-3177.

The routines that service keyboard commands are somewhat isolated so that they may be removed or altered. Many subroutines, however, are frequently used, and care should be taken if they are to be altered (e.g., FPI). To conserve storage space, we used locations 20-23 (TEMS20-23) as truly temporary storage; i.e., their use is intended to be internal to a routine and not to store information while using VAMP subroutines. This also applies to the auto index registers 10-17. The routines are grouped by computer pages and are discussed below.

Indirect addresses of all major subroutines are located on Page 0. In particular, the keyboard routine addresses are stored sequentially in locations 100-136. This sequence corresponds (address-wise) to the table of mnemonics on Page 13 and should not be altered. This arrangement affords minimum effort for adding new routines. The procedure for entering new keyboard commands is as follows:

a. Subroutines

- (1) Enter the starting address of the subroutine in location 115, 116, or 117 on Page 0.
- (2) Code* the keyboard calling letters.
- (3) Enter the coded number in the corresponding location 3315, 3316, 3317.

b. Fixed-point, Single-precision Integer Input

- (1) Code* the keyboard calling letters.
- (2) Enter the coded number in location 3325, 3326, 3327, or 3330.

The input number will then be stored in the corresponding location 125, 126, 127, or 130 on Page 0.

c. Floating-point Input

- (1) Enter the starting address of the three words of floating-point storage in location 131, 132, 133, 134, 135, or 136 on Page 0.

*The coding operation consists of placing the last two ASCII code values (octal) of each letter side by side, and then negating the result.

- (2) Code* the keyboard calling letters.
- (3) Enter the coded number in the corresponding location 3331, 3332, 3333, 3334, 3335, 3336.

The input number will then be stored indirectly with address on Page 0.

d. Nonstandard Numerical Input

- (1) Code* the keyboard calling letters.
- (2) Enter the coded number in location 3341, 3342, or 3343.
- (3) Enter the starting address of the subprogram in the corresponding location 3361, 3362, or 3363.

For example, consider a Subroutine called QZ located at 3004. The procedure is then as follows:

- (1) Enter 3004 in, say, location 116, on Page 0.
- (2) The ASCII code for Q is 321, for Z is 332. Therefore QZ is coded 2132. Enter this number in location 3316. QZ is now a regular member of the keyboard control family.

2. Page 13 Routines

- BEGIN:** Generates a CR-LF, rings a bell, and reads and interprets input teletype commands. This is accomplished by keeping two tables, one of command mnemonics and one of command addresses. If no legal command is found, a "?" is typed and the program is restarted. Once the mnemonic is found, the corresponding address on Page 0 (TEMS22) and the contents of that address (TEMS23) are saved.
- TABLE:** Contains the mnemonics of subroutine commands. Addresses of routines are in corresponding locations on Page 0.
- ONE:** Contains the mnemonics of fixed point-single precision integer input commands. Storage is in the corresponding locations on Page 0.
- TWO:** Contains the mnemonics of floating point input commands. Addresses of storage are in corresponding locations on Page 0.
- THREE:** Contains the mnemonics of "irregular" commands. Addresses of storage are in corresponding locations on the current page.
- FPI:** Allows numerical input via the floating-point package. Leading literal characters are ignored, while the input number may be terminated by any nonnumerical character. Input is stored in the floating accumulator.

*The coding operation consists of placing the last two ASCII code values (octal) of each letter side by side, and then negating the result.

SUBR: Serves the subroutine commands and routes completion back to BEGIN.

FIXED: Serves fixed-point input commands. Calls FPI for input and SINK to convert to integer. Return is to BEGIN.

FLOAT: Serves floating-point numerical input. Return is to BEGIN.

JUMP: Serves the irregular commands. There is no return.

3. Page 14 Routines

DISP: See Keyboard Control DS (p. 8). Routine has only one exit: manually setting Bit 0 of SR.

DISPLY: Adds superimposition to DISP. Routine has only one exit: manually setting Bits 0 and 1 of SR.

SWEEP1: Displays the number of data points contained in TEMS23 starting at the address contained in ORIGIN.

Exits: 1. Via light pen

Computer address of point is stored in TEMS21;
x-coordinate of point is stored in XCOR.

2. Via switch register

Bits

0	Exit DISP
0,1,2	Exit to DISP+1

PNSPFS: Divides full scale on scope (1024) by the number of points to be displayed (C[AC]) to determine point spacing PNTSP. Number of points is saved in TEMS23.

4. Page 15 Routines

PNTINQ: Types channel number and data of computer address held in TEMS21. (Output is shown in Section III-B-4.)

EXPINA: Performs integration routine. (Output is shown in Section III-B-4.)

CHANPR: Converts computer address of data held in the AC to channel number and outputs.

SSUM: Sums data from computer address held in the AC to computer address held in the MQ. HLT if $MQ \leq AC$; no recovery possible. Sum held in floating-point storage called indirectly by LNTSUM.

LNMFAL: Loads the double-precision integer held in the AC and MQ into the floating accumulator in normalized form.

CNTRAT: Sums data between addresses held in AC and MQ, divides sum by the run time, and outputs count rate.

Sum is stored indirectly in LNTSUM (floating point).

Count rate is stored indirectly in ATFPS1 (floating point).

CO: See Keyboard Control (p. 12).
CZ:

5. Page 16 Routines

NTCHGE: See Keyboard Control IN (p. 12).
ENABLE: ED (p. 8).

INTER: Performs interrupt service routine for interrupts other than power failure. C(AC) is stored in SAVEAC. If the clock flag has caused the interrupt, the program sequence goes to SETCLK, which indexes the clock (double precision), and returns to the interrupted program via CONTIN. If the clock is full, the program sequence goes to STOP. If the clock did not originate the interrupt, the ADC flag is tested. When the ADC causes an interrupt, the data are brought to the AC, negated, and stored in CHANNL. This is then checked against the discriminator window (i.e., LS-HS). If CHANNL is within the window, the channel is incremented and the program goes to CONTIN; otherwise, the program immediately returns to CONTIN. If neither the clock nor ADC caused the interrupt, the program sequence goes to OTHER.

OTHER: Tests for keyboard and light-pen interrupts.

When the keyboard interrupts, the program goes to READST, which reads the input character and checks for the letter S and then the letter T. If ST is typed, the program sequence goes to STOP; otherwise the program sequence goes to CONTIN (i.e., the keyboard is ignored, except for ST).

When the light pen interrupts, the program goes to PIE, which calls PNTINQ (point inquiry), clears the light-pen flag, and returns control to ENABLE+12.

CONTIN: Restores accumulator from SAVEAC, turns on the interrupt, and returns program control to the point of interruption.

STOP: Disables the ADC, and exits ENABLE.

PIE: See OTHER above.

READST: See OTHER above.

TYPE: See Keyboard Control C; (p. 12).

CLEAR: Stores zeros in the number of locations held in the AC, starting with the location held in SETTING. Before entry to other VAMP routines, SETTING must be restored to 0200.

CLDATA: See Keyboard Control CD (p. 8).
CLHALF: See Keyboard Control CH (p. 8).

6. Page 17 Routines

ANALYZ: See Keyboard Control AN (p. 12).

ANAL: Can be called without entrance into the floating-point inquiry. Enter with the factor in the floating accumulator.

SINK: Converts the number held in the floating accumulator to a double-precision integer with the low order held in the MQ and the high order held in the AC. Conversion takes place for numbers $\leq 4,194,303$, and routine zeros numbers of greater magnitude.

GETCL: Floats the double-precision clock and converts from pulses to time units. The result is stored in the floating accumulator.

ACMQPT: Prints a space, then the double-precision integer held in the AC (high order) and MQ (low order). Leading zeros are suppressed.

PSETIM: See Keyboard Control TT (p. 8).
DOUBLE: See Keyboard Control CK (p. 8).

SETUP: Sets up the floating-point package to output the number in the floating accumulator in six-digit form with three digits to the right of the decimal point.

RNTIM: See Keyboard Control RT (p. 8).
BPUN: See Keyboard Control PN (p. 12).

PLOT: Generates approximately 2 ft. of leader or trailer.

BINP: See Digital 8-5-U.

PRINT: See Keyboard Control PT (p. 12).

CRLF: Prints a carriage return-line feed combination.

7. Changes in the Floating-point Package

OUT1: Prints the content of the AC, with the interrupt off. Exit; teleprinter flag cleared, C(AC)=0.

READ: Reads a character from the teletype, and stores and prints the same character. Routine then checks the character for blank tape, which it ignores. Character storage is in location 57.

MARK: Generates a vertical line marker through the x-coordinate point held in the AC.

APPENDIX B

VAMP Program Listing

/FOR USE WITH FLOATING POINT PACKAGE WITH
/EAE S-5-D-S-EAE

		SNC=6121	/SKP ON NOT CLOCK
		SPL=6102	/SKP ON POWER FAILURE
		ASF=6111	/SKP ON ADC FLAG
		ARR=6116	/READ ADC INTO AC
		NAADC=6124	/ENABLE ADC
		DAADC=6134	/DISABLE ADC
		ACF=6114	/CLEAR ADC FLAG
	*1		
0001	6102	SPL	/SKIP ON POWER FAILURE
0002	5405	JMP I LINTER	
0003	7402	HLT	
0004	5076	AKFPP1,	/ADDR. OF FLOATING POINT CONSTANT 1
0005	4046	LINTER,	
0006	5123	ATFPS1,	/ADDR. OF FLOATING POINT TEMP STORG
0007	5600	LFLPT,	/FLOATING POINT PACKAGE
0010	0000	INDEX0,	
0011	0000	INDEX1,	
0012	0000	INDEX2,	
0013	0000	INDEX3,	
0014	0000	INDEX4,	
0015	0000	INDEX5,	
0016	0000	INDEX6,	
0017	0000	INDEX7,	
0020	0000	TEMS20,	
0021	0000	TEMS21,	
0022	0000	TEMS22,	
0023	0000	TEMS23,	
0024	3675	LSSUM,	
0025	4311	LACMQP,	
0026	7200	OUT,	/FLOATING POINT OUTPUT
0027	7400	INPUT,	/FLOATING POINT INPUT
0030	4550	LCRLF,	
0031	3730	LLNMFA,	
0032	7344	LPRT1,	
0033	7157	LREAD,	
0034	4257	LSINK,	
0035	3344	LFPI,	
0036	3202	BACK,	
		BEGIN+2	
		*55	
0055	0077	K77,	
0056	2000	KP1024,	
		*63	
0063	0000	XCOR,	
0064	5126	LKZERO,	/ADDR. OF FLOATING CONSTANT ZERO
0065	6375	LNTSUM,	
0066	5101	AKFPP2,	/ADDR. OF FLOATING POINT POSITIVE 2
0067	7600	MSETT,	
0070	0200	SETTNG,	
0071	4273	LGETCL,	
		*100	
0100	3760	LCO,	
0101	3766	LCZ,	
0102	3544	LDISPY,	
0103	4162	LCDATA,	
0104	4167	LCLHLF,	

0105	4400	LBPUN,	BPUN
0106	4471	LPRINT,	PRINT
0107	4026	LNABLE,	ENABLE
0110	4370	LRNTIM,	RNTIM
0111	4341	LPSTIM,	PSETIM
0112	4000	LNTCHG,	NTCHGE
0113	4141	LTYPE,	TYPE
0114	4200	LANALY,	ANALYZ
0115	0000		0
0116	0000		0
0117	0000		0
0120	0000	LOWSET,	0
0121	0377	HISET,	377
0122	0000	LOWCHN,	0
0123	0377	HICHAN,	377
0124	0400	FSCHAN,	400
0125	0000		0
0126	0000		0
0127	0000		0
0130	0000		0
0131	0000		0
0132	0000		0
0133	0000		0
0134	0000		0
0135	0000		0
0136	0000		0

*172			
0172	0027	CLOCK0,	27
0173	0000	CLOCK2,	0
0174	0000	CLOCK1,	0
0175	0027	SETIME,	27
0176	0002	HITIME,	2
0177	3420	LOWTIM,	3420

*3200			
3200	6032	BEGIN,	KCC
3201	6042		TCF
3202	4430		JMS I LCRLF
3203	1271		TAD BELL
3204	4432		JMS I LPRT1
3205	4433	CMMDAND,	JMS I LREAD
3206	0055		AND K77
3207	7106		CLL RTL
3210	7006		RTL
3211	7006		RTL
3212	3020		DCA TEMS20
3213	4433		JMS I LREAD
3214	0055		AND K77
3215	1020		TAD TEMS20
3216	3020		DCA TEMS20
3217	1277		TAD ADRSC3
3220	3013		DCA INDEX3
3221	1352		TAD CONTER
3222	3021		DCA TEMS21
3223	1020		TAD TEMS20
3224	1413		TAD I INDEX3
3225	7650		SNA CLA
3226	5234		JMP .+6
3227	2021		ISZ TEMS21
3230	5223		JMP .-5
3231	1276		TAD QUEST
3232	4432		JMS I LPRT1
3233	5202		JMP BEGIN+2
3234	1013		TAD INDEX3

/PAGE 13

/READ TWO CHARACTERS, PACK,

/AND STORE HERE

/STARTING ADDR. OF INPUT TABLE

/NUMBER OF ENTRIES IN TABLE

/COMPARE PACKED INPUT AND

/ITEM IN TABLE

/MATCH?

/YES

/NO. ALL ITEMS CHECKED?

/NO, CONTINUE

/YES, TYPE ? AND REBEGIN

/ADDRESS OF ITEM IN TABLE

3235	0272		AND MK177	
3236	3022		DCA TEMS22	/CORRESPONDING ADDR. ON PAGE 0.
3237	1422		TAD I TEMS22	
3240	3023		DCA TEMS23	/INDIRECT ADDR. STORED HERE
3241	1013		TAD INDEX3	/WHAT PART OF TABLE ARE WE IN?
3242	1273		TAD KONE	
3243	7510		SPA	
3244	5254		JMP SUBR	/SUBROUTINES
3245	1274		TAD KTWO	
3246	7510		SPA	
3247	5257		JMP FIXED	/FIXED PT, SINGL PRECISION INTEGERS
3250	1275		TAD KTHREE	
3251	7510		SPA	
3252	5264		JMP FLOAT	/FLOATING POINT
3253	5353		JMP JUMP	/IRREGULAR
3254	7200	SUBR,	CLA	
3255	4423		JMS I TEMS23	
3256	5202		JMP BEGIN+2	
3257	4344	FIXED,	JMS FPI	/READ VALID NO. & TERMINATG CHARACTER
3260	4434		JMS I LSINK	/BRING NO. INTO AC & MQ
3261	7701		CLA MQA	
3262	3422		DCA I TEMS22	
3263	5202		JMP BEGIN+2	
3264	4344	FLOAT,	JMS FPI	
3265	4407		JMS I 7	
3266	6423		FPUT I TEMS23	
3267	0000		FEXT	
3270	5202		JMP BEGIN+2	
3271	0207	BELL,	207	
3272	0177	MK177,	177	
3273	4460	KONE,	-ONE	
3274	7767	KTWO,	ONE-TWO	
3275	7772	KTHREE,	TWO-THREE	
3276	0277	QUEST,	277	/?
3277	3277	ADRSC3,	TABLE-1	
3300	7461	TABLE,	-0317	/CO-COUNT RATE ONE
3301	7446		-0332	/CZ-COUNT RATE ZERO
3302	7355		-0423	/DS-DISPLAY
3303	7474		-0304	/CD-CLEAR DATA, FULL SCALE
3304	7470		-0310	/CH-CLEAR DATA, HALF SCALE
3305	5762		-2016	/PN-PUNCH BINARY TAPE OF DATA
3306	5754		-2024	/PT-PRINT DATA
3307	7274		-0504	/ED-ENABLE
3310	5554		-2224	/RT-RUN TIME
3311	5354		-2424	/TT-TOTAL TIME
3312	6662		-1116	/IN-INTERCHANGE HALVES
3313	7405		-0373	/C;-COMMENTS
3314	7662		-0116	/AN-ANALYZE
3315	0000		0000	/EXPANDABLE
3316	0000		0000	
3317	0000		0000	
3320	6355	ONE,	-1423	/LS-LOW SETTING FIXED POINT
3321	6755		-1023	/HS-HIGH SETTING
3322	6375		-1403	/LC-LOW CHANNEL
3323	6775		-1003	/HC-HIGH CHANNEL
3324	7155		-0623	/FS-NO. OF CHANNELS IN FULL SCALE
3325	0000		0000	/EXPANDABLE
3326	0000		0000	
3327	0000		0000	
3330	0000		0000	
3331	0000	TWO,	0000	/EXPANDABLE FLOATING POINT
3332	0000		0000	
3333	0000		0000	

3334	0000	0000	
3335	0000	0000	
3336	0000	0000	
3337	7465	THREE,	-0313 /CK-CLOCK
3340	7462		-0316 /CN-CONTINUE: AFTER ED HAS BEEN STOPPED
3341	0000		0000
3342	0000		0000
3343	0000		0000
3344	0000	FPI,	0
3345	4427		JMS I INPUT /ENTER FLOATING POINT INPUT
3346	1060		TAD 60 /REGISTER # 0 IF VALID INPUT
3347	7650		SNA CLA
3350	5345		JMP -3
3351	5744		JMP I FPI
3352	7734	CONTER,	-44
3353	1356	JUMP,	TAD JMP1
3354	3355		DCA -+1
3355	0000		0
3356	5757	JMPI,	JMP I DBLE
3357	4351	DBLE,	DOUBLE
3360	4040	CTINU,	ENABLE+12
		*3400	
		DISP,	0
3400	0000		
3401	7240		STA
3402	1056		TAD KP1024
3403	3016		DCA INDEX6
3404	3014		DCA INDEX4
3405	1124		TAD FSCHAN
3406	4327		JMS PNSPFS
3407	1070		TAD SETING
3410	3370		DCA ORIGIN
3411	4245	EXPPAR,	JMS SWEEP1
3412	7604		LAS
3413	0277		AND MASK
3414	7650		SNA CLA
3415	5201		JMP DISP+1
3416	1021		TAD TEMS21
3417	3022		DCA TEMS22
3420	1063		TAD XCOR
3421	3014		DCA INDEX4
3422	4245		JMS SWEEP1
3423	1022		TAD TEMS22
3424	7141		CIA CLL
3425	1021		TAD TEMS21
3426	7510		SPA
3427	5201		JMP DISP+1
3430	7110		CLL RAR
3431	7001		IAC
3432	4327		JMS PNSPFS
3433	1022		TAD TEMS22
3434	3370		DCA ORIGIN
3435	3014		DCA INDEX4
3436	4245	RETURN,	JMS SWEEP1
3437	7604		LAS
3440	7104		CLL RAL
3441	7700		SMA CLA
3442	5774		JMP I LEXPNA
3443	4775		JMS I LPNTNQ
3444	5236		JMP RETURN
3445	0000	SWEEP1,	0
3446	6072		DCF
3447	7240		STA
3450	1370		TAD ORIGIN

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/MARKERS INITIALLY AT X=1023 AND
/X=0

/CHECK FOR NORMAL DISPLAY WHERE
/LIGHT PEN IS IGNORED

/EXPAND FM THIS LOW PT(CMPTR ADR)

/MOVE POINTER TO LOW POINT
/GET HIGH POINT

/HIGH POINT

/MUST HAVE LOW ≤ HIGH; OTHERWISE IGNORE
/DIVIDE DIFF OF COMPUTER ADDR BY 2

/NUMBER OF CHANNELS

/0 TO MARKER
/DSPLAY IS NOW EXPNDEN FM LOW PT THRU
/NO. OF PTS TO BE DISPLAYD (TEMS23)
/NEW POINT FROM LIGHT PEN
/CHECK SR FOR
/INTEGRATE OR
/POINT OF INQUIRY

3451	3011		DCA INDEX1	
3452	3063		DCA XCOR	/0-1024 ON SCOPE
3453	1023		TAD TEMS23	/NO. OF POINTS TO BE DISPLAYED
3454	3020		DCA TEMS20	
3455	7604		LAS	
3456	0372		AND MK17	
3457	3264		DCA SCALE	
3460	1411	REDISP,	TAD I INDEX1	/LOW ORDER FIRST
3461	7421		MQL	
3462	1411		TAD I INDEX1	/HIGH ORDER
3463	7413		SHL	
3464	0000	SCALE,	0	
3465	6063		DYL	
3466	7200		CLA	
3467	1063		TAD XCOR	
3470	6057		DXS	
3471	0055		AND K77	/SERVES AS: 6 μ S DELAY TIME IN CS OF LITE
3472	0277		AND MASK	/PEN AND AS CLA.
3473	6071		DSF	/IS FLAG SET?
3474	5307		JMP DCONT	/NO
3475	6054		DIX	/YES, REDISPLAY POINT
3476	7240		STA	/ALSO SRVS AS 1.5 μ S DELAY FOR PEN FLAG
3477	7000	MASK,	NOP	/1.5 μ S DELAY--ALSO USED AS A MASK
3500	6071		DSF	/HLD IN THIS LOOP TIL SHUTR IS CLOSD
3501	5304		JMP .+3	/CLOSED
3502	6072		DCF	
3503	5275		JMP .-6	
3504	1011		TAD INDEX1	
3505	3021		DCA TEMS21	/SAVE POINT
3506	5645		JMP I SWEEP1	/ONE WAY OUT - VIA LIGHT PEN
3507	1063	DCONT,	TAD XCOR	
3510	1371		TAD PNTSP	
3511	3063		DCA XCOR	/UPDATE
3512	2020		ISZ TEMS20	/ALL POINTS DISPLAYED?
3513	5260		JMP REDISP	/NO, CONTINUE
3514	1016		TAD INDEX6	/YES, MARKER AT X=1023 AND
3515	4773		JMS I LMARK	
3516	1014		TAD INDEX4	/X=0
3517	4773		JMS I LMARK	
3520	7604		LAS	/OTHER WAYS OUT OF SUBROUTINE ARE:
3521	0277		AND MASK	
3522	7510		SPA	
3523	5600		JMP I DISP	/BIT 0=1
3524	7640		SZA CLA	
3525	5246		JMP SWEEP1+1	/STAY IN SWEEP-WAIT FOR POINT
3526	5201		JMP DISP+1	/BITS 0, 1, 2 = 0
3527	0000	PNSPFS,	0	/ENTER W/NO.OF CHANELS IN FULL SCALE
3530	3333		DCA .+3	
3531	1056		TAD KP1024	/FULL SCALE ON SCOPE
3532	7427		MQL DVI	
3533	0000	DIVSOR,	0	
3534	7430		SZL	/DIVISION BY ZERO?
3535	5201		JMP DISP+1	
3536	7701		CLA MQA	
3537	3371		DCA PNTSP	/POINT SPACING
3540	1333		TAD DIVSOR	
3541	7041		CIA	
3542	3023		DCA TEMS23	/TEMP STRG FR NO.OF PTS DSPLAD (NEG)
3543	5727		JMP I PNSPFS	
3544	0000	DISPLY,	0	
3545	4200		JMS DISP	/CALL DISPLAY
3546	7604		LAS	/COME HERE ONLY IF BIT 0=1
3547	7106		CLL RTL	

3550	7630		CLA SZL	/CHECK BIT 1
3551	5744		JMP I DISPLY	/SET - RETURN TO COMMAND
3552	1017		TAD INDEX7	/NOT SET - SUPERIMPOSE HALVES
3553	7640		SZA CLA	/FIRST OR SECOND HALF
3554	5365		JMP SECOND	
3555	1124		TAD FSCHAN	/FIRST HALF OF FSCHAN IS NO. OF PTS.
3556	7110		CLL RAR	/IN THIS HALF
3557	4327		JMS PNSPFS	/GET POINT SPACING
3560	2017		ISZ INDEX7	/SET FLAG FOR NEXT TIME AROUND
3561	1070		TAD SETTING	
3562	3370		DCA ORIGIN	
3563	4245		JMS SWEEP1	/DISPLAY POINTS
3564	4775		JMS I LPNTNQ	/LIGHT PEN USED - POINT INQUIRY
3565	3017	SECOND,	DCA INDEX7	/0 TO FLAG
3566	1124		TAD FSCHAN	/SETTING + FSCHAN IS STARTING ADDR.
3567	5361		JMP --6	/OF SECOND HALF
3570	0000	ORIGIN,	0	
3571	0000	PNTSP,	0	
3572	0017	MK17,	17	
3573	6766	LMARK,	MARK	
3574	3614	LEXPNA,	EXPINA	
3575	3600	LPNTNQ,	PNTINQ	
			*3600	/PAGE 15
3600	0000	PNTINQ,	0	
3601	4430		JMS I LCRLF	
3602	1021		TAD TEMS21	/COMPUTER ADDR. OF POINT HERE
3603	4266		JMS CHANPR	/COMPUTE & PRINT CHANNEL NO.
3604	1421		TAD I TEMS21	/DATA - LOW ORDER
3605	7421		MQL	
3606	2021		ISZ TEMS21	
3607	1421		TAD I TEMS21	/HIGH ORDER
3610	4425		JMS I LACMQP	
3611	1063		TAD XCOR	
3612	3014		DCA INDEX4	/PUT MARKER ON POINT
3613	5600		JMP I PNTINQ	
3614	4430	EXPINA,	JMS I LCRLF	
3615	1063		TAD XCOR	
3616	3014		DCA INDEX4	/PUT MARKER ON LOWER POINT
3617	7604		LAS	/CHECK BIT 3 FOR REGION
3620	7106		CLL RTL	
3621	7106		CLL RTL	
3622	7620		SNL CLA	
3623	5250		JMP ZERO	/SET - REGION ZERO
3624	1021		TAD TEMS21	/NOT SET - REGION ONE
3625	3374		DCA LMARKO	/ADDR. OF LOWER LIMIT
3626	4743		JMS I LSWP1	/GET ADDR. OF UPPER LIMIT
3627	1021		TAD TEMS21	
3630	3375		DCA HMARKO	/ADDR. OF UPPER LIMIT
3631	1374		TAD LMARKO	
3632	4266		JMS CHANPR	
3633	1375		TAD HMARKO	
3634	4266		JMS CHANPR	
3635	4430		JMS I LCRLF	
3636	1375		TAD HMARKO	/SET UP FOR SSUM
3637	7421		MQL	
3640	1374		TAD LMARKO	
3641	4275	THERE,	JMS SSUM	
3642	1063		TAD XCOR	/PUT OTHER MARKER ON UPPER POINT
3643	3016		DCA INDEX6	
3644	3062		DCA 62	/0 = E FORMAT
3645	4426		JMS I OUT	/OUTPUT SUM
3646	4430		JMS I LCRLF	
3647	5742		JMP I PAGE1	

3650	1021	ZERO,	TAD TEMS21	/METHOD SAME AS REGION ONE
3651	3376		DCA LMARKZ	
3652	4743		JMS I LSWP1	
3653	1021		TAD TEMS21	
3654	3377		DCA HMARKZ	
3655	1376		TAD LMARKZ	
3656	4266		JMS CHANPR	
3657	1377		TAD HMARKZ	
3660	4266		JMS CHANPR	
3661	4430		JMS I LCRLF	
3662	1377		TAD HMARKZ	
3663	7421		MQL	
3664	1376		TAD LMARKZ	
3665	5241		JMP THERE	
3666	0000	CHANPR,	0	/ENTER WITH COMPUTER ADDR. IN AC
3667	1067		TAD MSETT	
3670	7110		CLL RAR	
3671	1120		TAD LOWSET	/LOWER CHANNEL OF WINDOW
3672	7421		MQL	/CHANNEL NUMBER
3673	4425		JMS I LACMQP	
3674	5666		JMP I CHANPR	
3675	0000	SSUM,	0	
3676	3020		DCA TEMS20	/LOWER LIMIT
3677	7240		STA	/DECREMENT FOR AUTO INDEX
3700	1020		TAD TEMS20	
3701	3011		DCA INDEX1	
3702	7501		MOA	/UPPER LIMIT
3703	7161		STL CIA /NEGATE-SET LINK FOR DIV-TO KP QUOTIENT NEG	
3704	1011		TAD INDEX1	/COMPARE WITH LOWER
3705	7500		SMA	/UPPER > LOWER?
3706	7402		HLT	/NO, HALT
3707	7010		RAR	/OK, DIVIDE DIFF. BY TWO
3710	3021		DCA TEMS21	/NO. OF CHANNELS TO SUM OVER (NEG)
3711	4407		JMS I 7	
3712	5464		FGET I LKZERO	
3713	6465		FPUT I LNTSUM	/0 TO SUM
3714	0000		FEXT	
3715	1411	NXTADR,	TAD I INDEX1	/LOW ORDER
3716	7421		MQL	
3717	1411		TAD I INDEX1	/HIGH ORDER
3720	4330		JMS LNMFA	/LOAD FAC
3721	4407		JMS I 7	
3722	1465		FADD I LNTSUM	/ADD TO SUM
3723	6465		FPUT I LNTSUM	
3724	0000		FEXT	
3725	2021		ISZ TEMS21	/ALL CHANNELS SUMMED?
3726	5315		JMP NXTADR	/NO, CONTINUE
3727	5675		JMP I SSUM	
3730	0000	LNMF,	0	/ENTER WITH DOUBLE PRECISION INTEGER
3731	7411		NMI	/IN AC(HIGH ORDER) & MQ(LOW ORDER)
3732	3045		DCA 45	
3733	7441		SCA	
3734	7041		CIA	
3735	1172		TAD CLOCK/CNSTNT 27-BINARY PT IS AT(MQ11-STEP CNTR)	
3736	3044		DCA 44	/EXPONENT
3737	7501		MOA	
3740	3046		DCA 46	
3741	5730		JMP I LNMFA	
3742	3436	PAGE1,	RETURN	
3743	3445	LSWP1,	SWEEP1	
3744	0000	CNTRAT,	0	
3745	4424		JMS I LSSUM	/SUM STORED INDIRECTLY IN LNTSUM
3746	4471		JMS I LGETCL	/CLOCK STORED IN FAC

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3747 4407 JMS I 7
3750 6020 FPUT TEMS20 /CLOCK
3751 5465 FGET I LNTSUM /GET SUM
3752 4020 FDIV TEMS20 /DIVIDE BY CLOCK
3753 6406 FPUT I ATFPS1 /SAVE RATE
3754 0000 FEXT
3755 3062 DCA 62
3756 4426 JMS I OUT /OUTPUT
3757 5744 JMP I CNTRAT
3760 0000 CO, 0
3761 1375 TAD HMARKO /SET UP FOR SSUM
3762 7421 MQL
3763 1374 TAD LMARKO
3764 4344 JMS CNTRAT
3765 5760 JMP I CO
3766 0000 CZ, 0
3767 1377 TAD HMARKZ
3770 7421 MQL
3771 1376 TAD LMARKZ
3772 4344 JMS CNTRAT
3773 5766 JMP I CZ
3774 0000 LMARKO, 0
3775 0000 HMARKO, 0
3776 0000 LMARKZ, 0
3777 0000 HMARKZ, 0
*4000 /PAGE 16
4000 0000 NTCHGE, 0
4001 1070 TAD SETTING /DATA STARTS HERE (200)
4002 3224 DCA LWHALF
4003 1124 TAD FSCHAN /NO.OF CHAN=NO.OF CMPTR ADRS IN 1/2 DATA
4004 1070 TAD SETTING
4005 3225 DCA HIHALF /THEN HIGH HALF STARTS HERE
4006 1124 TAD FSCHAN
4007 7041 CIA
4010 3023 DCA TEMS23
4011 1624 PURSUE, TAD I LWHALF /GET DATA FROM LOW HALF
4012 7421 MQL /TEMPORARY STORAGE
4013 1625 TAD I HIHALF /GET DATA FROM HIGH HALF
4014 3624 DCA I LWHALF /PUT IN LOW HALF
4015 7501 MQA /RETRIEVE TEMP
4016 3625 DCA I HIHALF /PUT IN HIGH HALF
4017 2224 ISZ LWHALF /NEXT ADDR. IN LOW
4020 2225 ISZ HIHALF /NEXT ADDR. IN HIGH
4021 2023 ISZ TEMS23 /ALL ADDRS. INTERCHANGED?
4022 5211 JMP PURSUE /NO, CONTINUE
4023 5600 JMP I NTCHGE
4024 0000 LWHALF, 0
4025 0000 HIHALF, 0
4026 0000 ENABLE, 0
4027 7300 CLA CLL /RESET RUNNING TIME CLOCK
4030 1177 TAD LOWTIM
4031 7041 CIA
4032 3174 DCA CLOCK1
4033 1176 TAD HITIME
4034 7040 CMA
4035 3173 DCA CLOCK2
4036 7430 SZL
4037 2173 ISZ CLOCK2
4040 6001 ION
4041 6124 NAADC /ENABLE ADC
4042 4502 JMS I LDISPY/RUN IN LOOP TIL PRESET TIME OR ST CMND
4043 5242 JMP -1 /IF BITS 0 & 1 ARE SET, IGNORE
4044 6134 STOP, DAADC /DISABLE ADC

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4045	5626		JMP I ENABLE	
4046	3316	INTER,	DCA SAVEAC	/SAVE AC
4047	6121		SNC	/SKIP IF NOT CLOCK
4050	5307		JMP SETCLK	
4051	6111		ASF	/SKIP ON ADC FLAG
4052	5277		JMP OTHER	
4053	6116		ARR	/READ ADC INTO AC - & RESET ADC FLAG
4054	7041		CIA	
4055	3315		DCA CHANNL	
4056	1315		TAD CHANNL	
4057	1121		TAD HISET	/CHANNEL < UPPER LIMIT OF WINDOW?
4060	7710		SPA CLA	
4061	5303		JMP CONTIN	/NO, IGNORE
4062	1315		TAD CHANNL	/YES. GREATER THAN LOWER LIMIT?
4063	1120		TAD LOWSET	
4064	7540		SMA SZA	
4065	5303		JMP CONTIN	/NO. IGNORE
4066	7041		CIA	/YES, THIS AMOUNT GREATER
4067	7104		CLL RAL	/MULT.BY 2-EA CHANNEL IS 2 REGISTERS
4070	1070		TAD SETTING	
4071	3315		DCA CHANNL	/CPTR ADDR OF LOW ORDER PT OF CHANNL
4072	2715		ISZ I CHANNL	/INCREMENT DATA IN THAT ADDR. FULL?
4073	5303		JMP CONTIN	/NO
4074	2315		ISZ CHANNL	/YES, NEXT ADDR. IS HIGH ORDER
4075	2715		ISZ I CHANNL	/INCREMENT
4076	5303		JMP CONTIN	
4077	6071	OTHER,	DSF	/LIGHT PEN OR
4100	6031		KSF	/TELETYPE?
4101	5317		JMP PIE	
4102	5326		JMP READST	
4103	7200	CONTIN,	CLA	
4104	1316		TAD SAVEAC	
4105	6001		ION	
4106	5400		JMP I 0	
4107	6114	SETCLK,	ACF	/CLEAR ADC FLAG
4110	2174		ISZ CLOCK1	/LOWTIM FULL?
4111	5303		JMP CONTIN	/NO
4112	2173		ISZ CLOCK2	/YES, PRESET TIME REACHED?
4113	5303		JMP CONTIN	/NO
4114	5244		JMP STOP	/YES
4115	0000	CHANNL,	0	
4116	0000	SAVEAC,	0	
4117	7240	PIE,	STA	
4120	1011		TAD INDEX1	
4121	3021		DCA TEMS21	/SETUP FOR POINT INQUIRY SUBROUTINE
4122	4725		JMS I PINQ	
4123	6072		DCF	/CLEAR LIGHT PEN FLAG
4124	5240		JMP ENABLE+12	
4125	3600	PINQ,	PNTING	
4126	4433	READST,	JMS I LREAD	
4127	1337		TAD MCHS	
4130	7440		SZA	
4131	5303		JMP CONTIN	
4132	4433		JMS I LREAD	
4133	1340		TAD MCHT	
4134	7440		SZA	
4135	5303		JMP CONTIN	
4136	5244		JMP STOP	
4137	7455	MCHS,	-323	/NEGATIVE S
4140	7454	MCHT,	-324	/NEGATIVE T
4141	0000	TYPE,	0	/ROUTINE IGNORES ALL CHARACTERS
4142	4433		JMS I LREAD	/EXCEPT "!"
4143	1347		TAD EXCLAM	

4144	7640		SZA CLA	
4145	5342		JMP TYPE+1	
4146	5741		JMP I TYPE	
4147	7537	EXCLAM,	-241	/NEGATIVE !
4150	0000	CLEAR,	0	
4151	7041		CIA	
4152	3020		DCA TEMS20	
4153	7240		STA	
4154	1070		TAD SETTING	
4155	3011		DCA INDEX1	
4156	3411		DCA I INDEX1	
4157	2020		ISZ TEMS20	
4160	5356		JMP --2	
4161	5750		JMP I CLEAR	
4162	0000	CLDATA,	0	/CLEARS DATA IN FULL SCALE CHANNELS
4163	1124		TAD FSCHAN	/NO. OF CHANNELS
4164	7104		CLL RAL	/TIMES 2 = NO. OF COMPUTER ADDRS.
4165	4350		JMS CLEAR	
4166	5762		JMP I CLDATA	
4167	0000	CLHALF,	0	
4170	1124		TAD FSCHAN	/NO. OF CHANNELS=NO. OF COMPUTER ADDRS. IN HALF
4171	4350		JMS CLEAR	
4172	5767		JMP I CLHALF	
		*4200		/PAGE 17
4200	0000	ANALYZ,	0	
4201	4435		JMS I LFPI	/GET FACTOR
4202	4204		JMS ANAL	
4203	5600		JMP I ANALYZ	
4204	0000	ANAL,	0	/ENTER WITH FACTOR IN FAC
4205	7240		STA	
4206	1070		TAD SETTING	
4207	3011		DCA INDEX1	
4210	1011		TAD INDEX1	
4211	3013		DCA INDEX3	
4212	1124		TAD FSCHAN	
4213	1070		TAD SETTING	
4214	3020		DCA TEMS20	/UPPER HALF
4215	7240		STA	
4216	1020		TAD TEMS20	
4217	3012		DCA INDEX2	
4220	1124		TAD FSCHAN	
4221	7110		CLL RAR	
4222	7041		CIA	
4223	3023		DCA TEMS23	/NO. OF CHANNELS IN HALF
4224	4407		JMS I 7	
4225	6465		FPUT I LNTSUM	/STORE FACTOR HERE
4226	0000		FEXT	
4227	1412	RELOAD,	TAD I INDEX2	/LOW ORDER &
4230	7421		SQL	
4231	1412		TAD I INDEX2	/HIGH ORDER OF CHANNEL IN UPPER HALF
4232	4431		JMS I LLNMFA	/PUT IN FAC
4233	4407		JMS I 7	
4234	3465		FMPY I LNTSUM	/MULTIPLY BY FACTOR
4235	6020		FPUT TEMS20	/TEMP. STORAGE
4236	0000		FEXT	
4237	1411		TAD I INDEX1	/LOW ORDER &
4240	7421		SQL	
4241	1411		TAD I INDEX1	/HIGH ORDER OF CHANNEL IN LOWER HALF
4242	4431		JMS I LLNMFA	/PUT IN FAC
4243	4407		JMS I 7	
4244	1020		FADD TEMS20	/ADD PREVIOUS CALC.
4245	0000		FEXT	
4246	4257		JMS SINK	/BRING INTO AC & MQ
4247	3021		DCA TEMS21	/HIGH ORDER

4250	7501	MQA	
4251	3413	DCA I INDEX3	/LOW ORDER
4252	1021	TAD TEMS21	
4253	3413	DCA I INDEX3	
4254	2023	ISZ TEMS23	/ALL CHANNELS?
4255	5227	JMP RELOAD	/NO, CONTINUE
4256	5604	JMP I ANAL	
4257	0000	0	
4260	1044	TAD 44	/EXPONENT
4261	7041	CIA	
4262	1272	TAD K22	/BINARY POINT IS AT MQ11-EXPONENT
4263	3270	DCA SHIFTS	
4264	1046	TAD 46	/LOW ORDER
4265	7421	SQL	
4266	1045	TAD 45	/HIGH ORDER
4267	7415	ASR	
4270	0000	0	
4271	5657	JMP I SINK	
4272	0026	26	
4273	0000	0	
4274	4407	JMS I 7	
4275	5172	FGET CLOCK0	
4276	7000	FNOR	
4277	6020	FPUT TEMS20	
4300	5175	FGET SETIME	
4301	7000	FNOR	
4302	1020	FADD TEMS20	
4303	4306	FDIV K1000N	
4304	0000	FEXT	
4305	5673	JMP I GETCL	
4306	0016	0016	
4307	2342	2342	
4310	0000	0000	
4311	0000	0	/ENTER WITH NO. IN AC & MQ
4312	4431	JMS I LLNMEA	/PUT IN FAC
4313	2046	ISZ 46	/CORRECT FOR CHOPPING ERROR
4314	2046	ISZ 46	
4315	1045	TAD 45	/HIGH ORDER 0?
4316	7650	SNA CLA	
4317	5324	JMP .+5	/YES
4320	1337	TAD K6	/NO, SET UP FOR FPP
4321	3062	DCA 62	
4322	4426	JMS I OUT	
4323	5711	JMP I ACMQPT	
4324	1337	TAD K6	/PRINT ZEROS OURSELF-FLOATING
4325	7041	CIA	/POINT TAKES TOO LONG
4326	3020	DCA TEMS20	
4327	1340	TAD SP	
4330	4432	JMS I LPRT1	
4331	2020	ISZ TEMS20	
4332	5327	JMP .-3	
4333	1336	TAD ZZZ	
4334	4432	JMS I LPRT1	
4335	5711	JMP I ACMQPT	
4336	0260	260	
4337	0006	6	
4340	0240	240	
4341	0000	0	/PRINTS PRESET TIME
4342	4407	JMS I 7	
4343	5175	FGET SETIME	
4344	4306	FDIV K1000N	/CONVERT FROM PULSES TO TIME UNITS
4345	0000	FEXT	
4346	4362	JMS SETUP	/OUTPUT
4347	5741	JMP I PSETIM	

4350	0003	K3,	3	
4351	4435	DOUBLE,	JMS I LFPI	/GET FLOATING POINT INTEGER
4352	4407		JMS I 7	
4353	3306		FMPY K1000N	/CONVERT TO PULSES
4354	0000		FEXT	
4355	4257		JMS SINK	
4356	3176		DCA HITIME	
4357	7501		MOA	
4360	3177		DCA LOWTIM	
4361	5436		JMP I BACK	
4362	0000	SETUP,	0	
4363	1337		TAD K6	
4364	3062		DCA 62	
4365	1350		TAD K3	
4366	4426		JMS I OUT	
4367	5762		JMP I SETUP	
4370	0000	RNTIM,	0	/PRINTS RUNNING TIME
4371	4471		JMS I LGETCL	
4372	4362		JMS SETUP	
4373	5770		JMP I RNTIM	
		*4400		/PAGE 18
4400	0000	BPUN,	0	
4401	7604		LAS	/BIT 0
4402	7700		SMA CLA	/UP
4403	1124		TAD FSCHAN	/DOWN-FULL NO. OF CHANNELS
4404	1124		TAD FSCHAN	/HALF
4405	1344		TAD KP6	
4406	7041		CIA	
4407	3022		DCA TEMS22	/NO. OF CHANNELS & CLOCKS TO PUNCH (NEG)
4410	1270		TAD STPUN	
4411	3011		DCA INDEX1	/SA OF CLOCKS
4412	3023		DCA TEMS23	/0 TO CHECK SUM
4413	4231		JMS PLOT	/PUNCH LEADER
4414	1270		TAD STPUN	
4415	7121		STL IAC	/SET LINK FOR SA
4416	4241		JMS BINP	
4417	7300		CLA CLL	
4420	1411		TAD I INDEX1	
4421	4241		JMS BINP	
4422	2022		ISZ TEMS22	
4423	5217		JMP --4	
4424	1023		TAD TEMS23	/CHECK SUM
4425	7100		CLL	
4426	4241		JMS BINP	
4427	4231		JMS PLOT	/TRAILER
4430	5600		JMP I BPUN	
4431	0000	PLOT,	0	
4432	1027		TAD INPUT	/-400
4433	3020		DCA TEMS20	
4434	1070		TAD SETTING	/200 = LEADER OR TRAILER
4435	4432		JMS I LPRT1	
4436	2020		ISZ TEMS20	
4437	5234		JMP --3	
4440	5631		JMP I PLOT	
4441	0000	BINP,	0	/SEE DIGITAL 8-5-U
4442	3020		DCA TEMS20	
4443	1020		TAD TEMS20	
4444	7012		RTR	
4445	7012		RTR	
4446	7012		RTR	
4447	0267		AND K177	
4450	3021		DCA TEMS21	
4451	1021		TAD TEMS21	
4452	4432		JMS I LPRT1	

4453	1021	TAD	TEMS21	
4454	1023	TAD	TEMS23	
4455	3023	DCA	TEMS23	
4456	1020	TAD	TEMS20	
4457	0055	AND	K77	
4460	3021	DCA	TEMS21	
4461	1021	TAD	TEMS21	
4462	4432	JMS	I LPRT1	
4463	1021	TAD	TEMS21	
4464	1023	TAD	TEMS23	
4465	3023	DCA	TEMS23	
4466	5641	JMP	I BINP	
4467	0177	K177,	177	
4470	0171	STPUN,	171	
4471	0000	PRINT,	0	
4472	1120	TAD	LOWSET	/LEFT-MOST CHANNEL HAS VALUE LOWSET
4473	7041	CIA		
4474	1122	TAD	LOWCHN	/LOWER CHANNEL TO PRINT
4475	7104	CLL	RAL	
4476	1267	TAD	K177	/ANY CHANNEL STARTS AT CPTR ADR. 200
4477	3011	DCA	INDEX1	
4500	7001	IAC		
4501	1123	TAD	HICHAN	
4502	7040	CMA		
4503	1122	TAD	LOWCHN	
4504	3023	DCA	TEMS23	/NO. OF CHANNELS TO PRINT
4505	4430	JMS	I LCRLF	
4506	4510	JMS	I LRNTIM	/RUN TIME PRINTED FIRST
4507	1122	TAD	LOWCHN	
4510	7421	MQL		
4511	4425	JMS	I LACMQP	/THEN FIRST CHANNEL NUMBER
4512	4430	JMS	I LCRLF	
4513	1345	CTLINE,	TAD KM10	
4514	3022		DCA TEMS22	/COUNTER FOR 10 LINES TO A GROUP
4515	1345	CTCHAN,	TAD KM10	/COUNTER FOR 10 CHANNELS TO A LINE
4516	3021		DCA TEMS21	
4517	2023	PRDATA,	ISZ TEMS23	/ALL CHANNELS PRINTED?
4520	7410		SKP	/NO
4521	5336		JMP LASTCH	/YES
4522	1411		TAD I INDEX1	/DATA - LOW ORDER
4523	7421		MQL	
4524	1411		TAD I INDEX1	/HIGH ORDER
4525	4425		JMS I LACMQP	/PRINT
4526	2021		ISZ TEMS21	/TENTH CHANNEL?
4527	5317		JMP PRDATA	/NO
4530	4430		JMS I LCRLF	/YES
4531	2022		ISZ TEMS22	/TENTH LINE
4532	5315		JMP CTCHAN	/NO
4533	4430		JMS I LCRLF	/YES
4534	4430		JMS I LCRLF	
4535	5313		JMP CTLINE	
4536	4430	LASTCH,	JMS I LCRLF	
4537	1123		TAD HICHAN	/PRINT LAST CHANNEL
4540	7421		MQL	
4541	4425		JMS I LACMQP	
4542	4430		JMS I LCRLF	
4543	5671		JMP I PRINT	
4544	0006	KP6,	6	
4545	7766	KM10,	-12	
4546	0215	CR,	215	
4547	0212	LF,	212	
4550	0000	CRLF,	0	
4551	7200		CLA	
4552	1346		TAD CR	

4553	4432	JMS I LPRT1	
4554	1347	TAD LF	
4555	4432	JMS I LPRT1	
4556	5750	JMP I CRLF	
	*7344		/CHANGES IN THE FLOATING POINT PACKAGE
7344	0000	OUT1,	0
7345	6046	TLS	/PRINT
7346	6041	TSF	/WAIT ON FLAG
7347	5346	JMP --1	
7350	6042	TCF	/CLEAR FLAG
7351	5231	JMP 7231	
	*7230		
7230	5233	JMP .+3	
7231	7200	CLA	
7232	5744	JMP I OUT1	
	*7223		
7223	5226	5226	
	*7225		
7225	7410	SKP	
	*7330		
7330	0255	255	
	*7327		
7327	0240	240	
	*7142		
7142	0000	INPU,	0
7143	4433	JMS I LREAD	
7144	1374	TAD MRBOUT	
7145	7450	SNA	
7146	5773	JMP I RESTRT	
7147	1375	TAD MINCR	
7150	7650	SNA CLA	
7151	5354	JMP .+3	
7152	1057	TAD 57	
7153	5742	JMP I INPU	
7154	1376	TAD LNFEED	
7155	4432	JMS I LPRT1	
7156	5352	JMP --4	
7157	0000	READ,	0
7160	7200	CLA	
7161	6031	KSF	
7162	5361	JMP --1	
7163	6036	KRB	
7164	3057	DCA 57	
7165	1057	TAD 57	
7166	4432	JMS I LPRT1	
7167	1057	TAD 57	
7170	7450	SNA	
7171	5360	JMP READ+1	
7172	5757	JMP I READ	
7173	7401	RESTRT,	7401
7174	7401	MRBOUT,	-377
7175	0162	MINCR,	377-215
7176	0212	LNFEED,	212
	*6766		
6766	0000	MARK,	0
6767	6053	DXL	/ENTER WITH X COORDINATE IN AC
6770	7200	CLA	
6771	1056	TAD KP1024	/HIGHEST POINT ON MARKER IS Y=1024 ₁₀
6772	6067	DYS	
6773	1266	TAD 6666	/THEN Y-64 ₁₀
6774	7500	SMA	
6775	5372	JMP --3	/ETC.
6776	7200	CLA	
6777	5766	JMP I MARK	

ACF	6114	MCHT	4140	INDEX6	0016
ACMQPT	4311	MINCR	7175	INDEX7	0017
ADRSC3	3277	MK17	3572	INPU	7142
AKFPP1	0004	MK177	3272	INPUT	0027
AKFPP2	0066	MRBOUT	7174	INTER	4046
ANAL	4204	MSETT	0067	JMPI	3356
ANALYZ	4200	NAADC	6124	JUMP	3353
ARR	6116	NTCHGE	4000	KM10	4545
ASF	6111	NXTADR	3715	KONE	3273
ATFPS1	0006	ONE	3320	KP1024	0056
BACK	0036	ORIGIN	3570	KP6	4544
BEGIN	3200	OTHER	4077	KTHREE	3275
BELL	3271	OUT	0026	KTWO	3274
BINP	4441	OUT1	7344	K1000N	4306
BPUN	4400	PAGE1	3742	K177	4467
CHANNL	4115	PIE	4117	K22	4272
CHANPR	3666	PINQ	4125	K3	4350
CLDATA	4162	PLOT	4431	K6	4337
CLEAR	4150	PNSPFS	3527	K77	0055
CLHALF	4167	PNTINQ	3600	LACMQP	0025
CLOCK0	0172	PNTSP	3571	LANALY	0114
CLOCK1	0174	PRDATA	4517	LASTCH	4536
CLOCK2	0173	PRINT	4471	LBPUN	0105
CMMAND	3205	PSETIM	4341	LCDATA	0103
CNTRAT	3744	PURSUE	4011	LCLHLF	0104
CO	3760	QUEST	3276	LCO	0100
CONTER	3352	READ	7157	LCRLF	0030
CONTIN	4103	READST	4126	LCZ	0101
CR	4546	REDISP	3460	LDISPY	0102
CRLF	4550	RELOAD	4227	LEXPNA	3574
CTCHAN	4515	RESTRT	7173	LF	4547
CTINU	3360	RETURN	3436	LFLPT	0007
CTLINE	4513	RNTIM	4370	LFPI	0035
CZ	3766	SAVEAC	4116	LGETCL	0071
DAADC	6134	SCALE	3464	LINTER	0005
DBLE	3357	SECOND	3565	LKZERO	0064
DCONT	3507	SETCLK	4107	LLNMFA	0031
DISP	3400	SETIME	0175	LMARK	3573
DISPLY	3544	SETTING	0070	LMARKO	3774
DIVSOR	3533	SETUP	4362	LMARKZ	3776
DOUBLE	4351	SHIFTS	4270	LNABLE	0107
ENABLE	4026	SINK	4257	LNFEED	7176
EXCLAM	4147	SNC	6121	LNMF	3730
EXPINA	3614	SP	4340	LNTCHG	0112
EXPPAR	3411	SPL	6102	LNTSUM	0065
FIXED	3257	SSUM	3675	LOWCHN	0122
FLOAT	3264	STOP	4044	LOWSET	0120
FPI	3344	STPUN	4470	LOWTIM	07
FSCHAN	0124	SUBR	3254	LPNTNQ	3575
GETCL	4273	SWEEP1	3445	LPRINT	0106
HICHAN	0123	TABLE	3300	LPRT1	0032
HIHALF	4025	TEMS20	0020	LPSTIM	0111
HISSET	0121	TEMS21	0021	LREAD	0033
HITIME	0176	TEMS22	0022	LRNTIM	0110
HMARKO	3775	TEMS23	0023	LSINK	0034
HMARKZ	3777	THERE	3641	LSSUM	0024
INDEX0	0010	THREE	3337	LSWP1	3743
INDEX1	0011	TWO	3331	LTYPE	0113
INDEX2	0012	TYPE	4141	LW HALF	4024
INDEX3	0013	XCOR	0063	MARK	6766
INDEX4	0014	ZERO	3650	MASK	3477
INDEX5	0015	ZZZ	4336	MCHS	4137

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