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DECUS NO.	8-145
TITLE	TIME-OF-FLIGHT ANALYZER
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SOURCE LANGUAGE	

ATTENTION

It operates as follows.

A magnetic pick-up mounted on the chopper sends a pulse to the converter at the moment when a neutron burst starts travelling down the flight path. This pulse is used to start a clock filling a counting register. When a neutron arrives at a certain detector the momentary state of the counting register is copied into a buffer and a program-interrupt-request is sent to the computer to start a subroutine for information handling. The counting register keeps running and can again be copied into the buffer by another neutron signal from the same burst, as soon as a reset has been received from the computer. To provide different channel widths, the interval between successive clock pulses can be varied from 1 to 64 μs. A zero time shift produced by a digitally controlled delay enables the analyzer to record only part of the spectrum on the full number of channels available.

A maximum of 3072 channels with a capacity of 4096 counts/channel is available for spectrum recording. By means of a switch it is possible to select modes to monitor 12, 6, 3 or 1 detectors with 256, 512, 1024 or 3072 channels respectively. The buffer, which is a 12 bit register, receives the information in coded form. For 12 detectors the four most significant digits represent the detector number and the remaining eight digits the time or channel information. For six detectors the three most significant digits give the detector number, and so on. A detailed technical description of the converter can be found elsewhere [1].

Explanations of the instruction code and the symbolic machine language for the PDP-8 are given in the "Small Computer Handbook" [x].

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[x] published by Digital Equipment Corporation, Maynard 1967

A TIME-OF-FLIGHT ANALYZER BASED ON
A SMALL ON-LINE COMPUTER(o)

Introduction

Experimental arrangements for time-of-flight (TOF) measurements can benefit from the inherent flexibility of fast on-line computers. The great strength of computer oriented TOF facilities is that very special experimental requirements can be dealt with by simple program modifications. Examples of such flexibility are:

1. different channel numbers can be assigned to different detectors for optimizing the information gain within the limitations of available storage capacity,
2. the spectrum display can be tailored to the convenience of the experimenter,
3. the format of data output can be adapted to the input requirements of other computers used for further data processing,
4. small scale data handling can be performed by the on-line machine itself between spectrum recordings, and
5. contrary to specialized analyzers, the on-line computer can be switched to a completely different job when the TOF experiment is ended.

The TOF-analyzer for which this program was written is in use [x] with a double chopper facility installed at the ISPRA-I reactor. It consists of

1. a PDP-8 on-line computer [xx] with a 4K memory, the automatic restart option, and a display unit,
2. a TOF-converter,
3. conventional counting electronics.

The counting electronics are not unusual, and therefore will not be described here. The TOF-converter provides the computer with digital information about the time a neutron takes to travel from the scattering sample to a detector (up to 12 detectors can be accommodated) and which detector was involved.

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tion is desired, the content of storage location 0174_8* must be changed from 0014_8 (= 12_{10}) to 0006, 0003 or 0001 respectively. The rotary switch on the converter has to be set correspondingly . The relationship between the addresses of storage locations can be seen in table 1. The starting address for the program is 0200_8. Upon being started, the computer responds with Teletype bell, carriage return (CR) and line feed (LF) and is ready to receive commands via the Teletype keyboard. There are ten basic commands with certain variations which will be described below. To indicate the non-printing characters ",CR" and "space" the symbols ⟩ and ⌣ respectively will be used.

N⟩ Disable data taking. The computer responds with LF. The computer continues on that part of program in progress before the N-command is given (normally this is the display program). When the program is first loaded, data taking should be disabled by N or Z-command because data taking is originally enabled.

X⟩ Enable data taking. The computer responds with LF. The computer continues on that part of program in progress before the X-command is given.

Z⟩ Clear all storage locations provided for spectrum recording. The computer responds with CR and LF. Data taking is disabled. The computer continues on that part of program in progress before the Z-command is given.

Z⌣xx⟩ Clear the storage locations assigned to the detector with number xx. The computer responds with CR and LF. Data taking is disabled. The computer continues on that part of program in progress before the Z-command is given. It should be noted, that the actual number of storage lo-

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*subscript 8 indicates that the number is given in octal form

Purpose of the program

The main purpose of this program is to enable the computer to interact with the TOF-converter. When the TOF-converter presents a digital time-of-flight datum and the number of the triggered detector to the PDP-8 by requesting a program-interrupt, the computer activates a subroutine enabling it to absorb the TOF information. If the information is valid, the memory location which is assigned to this particular detector-time combination must be incremented by one. If the information is invalid (impossible detector number), it has to be rejected to protect the program. If the incrementation results in an overflow, a message must be given to indicate the number of the channel and the detector involved. The remaining part of the program, which occupies most of the storage locations provided for programming, is responsible for the input and execution of commands. These commands correspond to the various controls which can be found on fixed-wired TOF-analyzers. They are transmitted to the computer via a Teletype keyboard. There are commands for different kinds of spectrum display on an oscilloscope, different modes of spectrum output on punched paper tape or typewriter and a command for reloading of previously punched spectrum tapes. A detailed decription of all commands is given on page 8. Moreover, the program has to do some housekeeping. For instance, it has to keep permanent watch on the automatic restart unit, which raises a flag when the line voltage goes below a certain safety level. When this happens the program has to transfer the contents of all relevant flip-flop registers into the core-memory and stop computation. When the line voltage returns above the safety level the flip-flop registers must be reset to their previous values and the computation resumed.

Operation Commands

When the program has first been loaded the computer is set to handle the case of 12 detectors. If another detector configura-

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setting, enabling, disabling of data taking and overflow handling are done as for the D)-command.

D␣xx␣xxxx) The same is done as for the D xx command except that the position of the lower marker is specified by the given four-digit decimal number. The upper marker is at the highest channel position. Note that the number of the lowest channel is zero in every group.

D␣xx␣xxxx␣xxxx) The same is done as for the D xx xxxx command except that the position of the upper marker is specified by the second four-digit decimal number.

D␣xx␣xxxx␣xxxx␣xx) The same is done as for the D xx xxxx xxxx command except that in addition the content of a second detector specified by the last two-digit decimal number is displayed. The sensitivity of the display for the second character is set to the lowest possible value of 4096 counts/full screen height.

E) Expands the area of display between the markers over the maximum possible screen width. If this area contains less than 1024 points, all channels will be displayed. This is also the case if the original, non-expanded display was done in skip mode (see D-command). The E-command does not change the state of data taking. If the command for display of two spectra was given before, both spectra will be displayed in the expanded mode. The sensitivity settings are not changed.

cations cleared by this command depends on the number stored in location 0174_8.

D)   Display the contents of all memory locations provided for spectrum recording. The computer responds with LF. Markers are displayed at the position of lowest and highest channels. Markers are vertical lines extending over the full screen heigth. Since only 1024 different data points are available along the display abscissa, only every third channel can be shown. Interval markers are displayed along the abscissa (see Fig. 1). The display sensitivity is set to the lowest possible value of 4096 counts/full screen height. The interrupt is turned on and if data taking has been enabled data are accepted and recorded in the proper channel. If an overflow occurs in a certain channel a message is punched and/or printed on the Teletype: "xxxx xx FULL", where the first four characters give the channel and the next two the detector number. During this print-out data taking is disabled. The channel is then set to zero and data taking is re-enabled. The display continues. Data taking can be stopped with an N-command without interrupting the display. The display will not be completely flicker-free, however, especially when there is a high rate of data input, but this does not present any difficulties because the display is made with a storage oscilloscope.

D⌣xx)   Display the content of the memory locations assigned to detector xx (xx is a two-character decimal number. To give a one digit number like 2, one has to type 02). This assignment depends on the number stored in memory location 0174_8. Markers are shown at lowest and highest channel positions. If the number of channels to be displayed is greater than 1024, channels are skipped as explained above. Sensitivity

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M) Loads a binary spectrum tape in additive mode. The computer responds with LF. The tape must be put on the read station and the reader must be started. The spectrum from the tape is read-in and added to the spectrum already in the memory. If the spectrum on the tape has only to be transfered into the memory a Z-command must precede. When the tape is read-in, the computer halts. One then has to switch off the reader and press the "CONTINUE" key on the computer. The program then waits for the next command. The M-command disables the data taking. During its execution the display does not continue. If a measurement requires all data channels, the RIM and BIN-loaders, which normally occupy the last memory locations, are lost. To avoid the manual procedure to load RIM via the computer switch board a small tape is provided called "TOF binary loader", which can be loaded by means of a Z-M-command combination. It restores both loading routines RIM and BIN.

Description of the program

This program results from a major modification of the DEC program "One Dimensional Display and Analysis". It was written in the symbolic machine language and assembled with MACRO-8. The program listing, which is given in the appendix, is an assembler generated print-out established during the third pass. The first column gives the number of the storage location and the second its content. Both numbers are given in octal form. They represent the result of the compilation. The third column gives a symbolic address (which is optional), separated by comma from a datum or an instruction in the fourth column. In a last column an optional comment is given, separated from column four by a slash. These comments are ignored by the assembler.

When the program is started at location 0200_8 the computer responds with Teletype bell, CR and LF using the subroutine PRINT1. Transfer is made to the READRT subroutine, where the

Lx   Changes the sensitivity of display for the detector whose
      number was typed on the left hand side of the lower mar-
      ker position in the preceding D-command. The sensitivity
      is changed to "lowest sensitivity times 2^X", where x is
      a decimal digit. The computer responds with a space-cha-
      racter. The computer continues on that part of program
      in progress before the last interrupt occured. Use of a
      CR as command terminator was avoided in this case to sa-
      ve paper. A following D-command will override this sen-
      sitivity setting and will set it back to the lowest pos-
      sible value.

Ux   Changes the sensitivity of display for the detector whose
      number was typed on the right hand side of the upper mar-
      ker position in the preceding D-command. The other spe-
      cifications are the same as for the Lx-command.

W)   Prints the contents of all memory locations between and
      including the markers in decimal form. A D-command must
      precede to define the position of the markers. The com-
      puter responds with LF. The printed lines contain in their
      left-hand column the channel number, and in the ten co-
      lumns on right the number of counts in that and the nine
      succeeding channels. This command disables the data ta-
      king. The display continues.

P)   Punches the contents of all memory locations between and
      including the markers in BIN-format (see Small Computer
      Handbook). A D-command must precede to define the posi-
      tion of the markers. The computer responds with LF. This
      command disables data taking. The display continues.
      Tapes punched by this command can be reloaded into the
      memory by means of the M-command (see below) or
      by means of the BIN-loader. Because the BIN-loader
      occupies the storage locations from 7612_8 to 7755_8 (which
      is in the block provided for spectrum recording) not all
      channels can be loaded in this way.

1. Data taking must be disabled.
2. During the very slow mechanical print operation the program branches to that part of program which was in progress as the previous program interrupt was acknowledged. Normally this will be the display routine. When the print operation is ended, program is called back to the PRNTIR subroutine. This feature is used in P and W-commands to keep the display running during data output.

On memory page 6 there is location BEGIN (0200_8) where the program must be started. Following the location CMMAND, ten basic commands are decoded and transfer is made to the proper subprogram.

WRITE,   After data taking has been disabled the content of all channels between the markers is printed out in decimal form using the PRNTIR routine. The display keeps running. A D-command must precede to define the marker positions. LOMARK and HIMARK are the memory addresses of the channels which correspond to the marker positions. LSTORE is the address of channel zero. The form of the print-out has already been described.

ENABLE,   Data taking is enabled by transfering the instruction JMP OTHER1 to INTER.

DSABLE,   Data taking is disabled by transfering the instruction JMP TTINTR to INTER.

Memory page 7:

RE1,   This short program is used as terminator for subprograms which pass control back to the display routine as WRITE does.

OVRFLO,   If a channel gets an overflow as result of an incrementation the channel and detector-number involved

computer waits for a command to be typed. If this command is
given, it is decoded and transfer is made to the program
which executes that particular job. If a character is typed,
which does not correspond to one of the ten basic commands, it
is rejected and the program goes back to wait for another com-
mand.

If, during the execution of a basic command, an ION instruc-
tion is encountered, the program interrupt will be enabled.
In this case the computer is ready to answer program interrupt
requests. The interrupt handling routine is stored on memory
page 5. There are several sources of program interrupt signals,
which are dealt with according to a certain hierachy of prio-
rities. The highest priority is assigned to the automatic re-
start unit, which requests a program interrupt in the case
of mains failure. The program acknowledges the interrupt,
stores the content of accumulator, link and program counter in
the core memory and waits for power restoration. Then it re-
sumes computation where it was interrupted.

The state of data taking is controlled by the content of
storage location INTER. When data taking is enabled it con-
tains the instruction JMP OTHER1, otherwise JMP TTINTR. In
the first case TOF interrupts will be acknowledged, in the se-
cond one they will be rejected. Before a TOF datum is read-in,
the content of accumulator and link are stored, then the in-
formation is transfered into the computer, the storage location
of the involved channel is calculated and a test performed to
check if the TOF-datum is valid. The channel is incremented
and tested for overflow. If this is the case, transfer is
made to a special part of the program.

The following two subroutines are also stored on memory page 5.

PRINT1, The content of accumulator bits 4 to 11 is printed
        (and punched) on Teletype according to the ASCII code.

PRNTIR, The same function as PRINT1 is performed with the fol-
        lowing exemptions:

Program goes back to the display routine. There-
fore the channels between the markers are displayed
over the maximum range on the screen compatible
with the number of data points along the abscissa.

Memory page 9

WMARK,   From the contents of DETRNR and PRODCT the memory
          addresses of first and last channels corresponding
          to a selected detector are calculated. PRODCT con-
          tains the binary equivalent of a detector number
          given with a basic command. The result will be sto-
          red in WLMARK and WHMARK.

PUNCH,   The contents of all channels between and including
          the position of the markers are punched in binary form.
          The memory addresses of highest and lowest channels
          are HIMARK and LOMARK respectively. Some length of
          leader-trailer-code precedes and follows the data
          on tape. The loading conventions followed with
          PDP-8 programs are applied, so that the tape could
          be loaded with the BIN-loader.

SCALE,   The subroutine produces the scale marker attached
          to the abscissa on display.

MARK,   The subroutine produces a marker on the display.
          Markers are vertical lines displayed over the full
          screen height.

Memory pages 10 and 11

DSPLAY,   This subprogram, which occupies page 10 and 11 controls
          the display. It consists of three parts.
          1. Decode display specifications. The additional
             information which can optionally be typed fol-
             lowing a D-command is decoded. The range of sto-
             rage locations corresponding to the selected de-

are calculated using the information from DETRNR. Detector and channel-number are printed in decimal form (CASEX) followed by the text "FULL)LF" (PRFULL).

INPUT4,   A four-digit decimal number is read via Teletype keyboard and converted to a binary integer.

INPUT2,   A two-digit decimal number is read via Teletype keyboard and converted to a binary integer. This program modifies temporarily a parameter in INPUT4 and uses that routine.

READRT,   A character is read via Teletype keyboard and its binary equivalent stored in HOLD1. If the character read is a rubout, the program passes control back to BEGIN after having restored instruction at INPUT4+1 to its original form.

Memory page 8:

CLDATA,   Data taking is disabled. If the character read after the Z-command was given is different from CR, two additional characters are requested from the keyboard. This information is used to calculate the range of storage locations, which are thereafter zeroed.

SHIFTL,   A number is shifted to the left. The number to be shifted must be in SHFTRG. The number of required left-shifts has to be given in the accumulator (a negative number means right-shift, zero means no shift at all). The result is generated in SHFTRG. The accumulator contains zero.

PNTDEC,   A binary integer from location LOW is converted and printed as a four-digit decimal number. It uses the PRNTIR subroutine.

EXPAND,   The contents of LOMARK and HIMARK are tranfered to locations WLMARK and WHMARK, which represent the values for the screen boundary channels respectively.

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If (WHL) exeeds 1024 not all channels can be displayed. In this case another constant is calculated:

MINC: Memory location increment for consecutive data points to be displayed on screen.

3. Do the display (INDSPL). The computer will cycle through this program to keep the display alive. Going from left to right, for every abscissa value from (SLMARK) to (SHMARK) the following items are displayed:
Point on the abscissa
Scale marker, if required,
Marker (vertical line), if required,
One or two data points, if required.

Memory page 12

BINPCH,   This subroutine punches the content of the accumulator in the form of two successive characters on tape. A checksum is updated.

CHECK,   The subroutine accumulates a checksum in LOW.

LEADIN,   Some length of leader-trailer-code (200) is punched on tape.

LOWER,   It changes the sensitivity of display for the detector specified on the left-hand-side of the marker specification in a preceding D-command.

UPPER,   It changes the sensitivity of display for the detector specified on the right-hand-side of the marker specification in a preceding D-command. If this detector was not specified, nothing happens.

LOAD,   This subprogram reads a binary spectrum tape previously generated by a P-command. The spectrum is added to the contents of the involved storage

tector is calculated (WLMARK, WHMARK). If no additional specifications have been given, LOMARK and HIMARK are set to 2000_8 and 7777_8 respectively. If marker specifications have been typed, these are used to calculate LOMARK and HIMARK according to

low marker specification + (WLMARK)[*]$\Rightarrow$LOMARK

high marker specification +(WLMARK)$\Rightarrow$HIMARK.

If a second detector is selected, the location for its channel number zero (XLMARK) is determined and the display program is prepared for multiple display.

2. Calculate screen markers. All channels from location WLMARK to location WHMARK are displayed on the screen, if (WHMARK)-(WLMARK)$\Rightarrow$WHL does not excede 1024 (maximum possible data points along abscissa). To use as much space as possible on the screen for the display of the spectrum (especially important for the expand mode of display), (WHL) is successively multiplied by two. If the result exceeds 1024, the process is terminated. The number of multiplications is used to calculate the screen markers:

SLMARK: Abscissa on screen for the lowest channel to be displayed

SHMARK: Abscissa on screen for the highest channel to be displayed

SLOMRK: Abscissa on screen for low marker

SHIMRK: Abscissa on screen for high marker

SINC : Abscissa increment for consecutive data points on the screen.

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[*])
Brackets indicate content of storage location named.

4.   Place BIN loader into memory as follows
4.1.   Put the BIN loader tape on the reader
4.2.   Set starting address 7756 in SR
4.3.   Press "Load Address"
4.4.   Press "Start"
4.5.   Start the reader
4.6.   If the trailer code passes the reader, stop it (on rea-
        der and computer)
5.   Load time-of-flight (TOF) program as follows
5.1.   Put the TOF tape in the reader
5.2.   Set starting address 7777 in SR
5.3.   Press "Load Address" and
5.4.   Press "Start" and start the reader
5.5.   When the reader stops, check if accumulator (AC) con-
        tains zero. If yes, continue; if not, reading error has
        occured. Return to 5.1.
6.   Prepare display unit
6.1.   Switch on oscilloscope
6.2.   Set "Vertical Sensitivity" to 1 volt/cm
6.3.   Set "Horizontal Sensitivity" to 1 volt/cm
6.4.   Set "Horizontal Display" to "Horizontal Amp.Only"
6.5.   Set vertical and horizontal input switches to DC
6.6.   Set position controls to approximately 12 o-clock
7.   Switch on power supply for TOF converter
8.   Set starting address 0200 in SR[*]
9.   Press "Load Address"
10.   Press "Start"
11.   Give command D 01 and observe oscilloscope
12.   Adjust sensitivity verniers (red knobs), focus and in-
        tensity to suit
13.   Give keyboard commands as required

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[*] It is assumed that DETRNR which is stored at 0171 already
     has its correct value; if not, it should be corrected
     before step 8.

locations. If an overflow occurs, the memory lo-
cation is set to 7777_8.

BINRD,   The subroutine reads a binary character (from
tape) into HOLD1.

Program loading

1.   Switch on PDP-8
2.   Switch on Teletype for on-line operation
3.   Place RIM loader into memory as follows:
3.1. Set 7756[*] in the switch register (SR)
3.2. Press "Load Address"
3.3. Set the first instruction (6032) in the SR
3.4. Press "Deposit"
3.5. Set the next instruction (6031) in the SR
3.6. Press "Deposit"
3.7. Repeat 3.5 and 3.6 until all instructions have been de-
posited. The RIM instructions are:

address	content
7756	6032
7757	6031
7760	5357
7761	6036
7762	7106
7763	7006
7764	7510
7765	5357
7766	7006
7767	6031
7770	5367
7771	6034
7772	7420
7773	3776
7774	3376
7775	5356
7776	0000
7777	5000

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[*])
  instructions and storage locations are given in octal

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                    /TIME OF FLIGHT PROGRAM
                    *0
0000  0000                  0
0001  6102                  SPL                    /IS IT LOW POWER?
0002  5014    INTER,        JMP OTHER1             /NO
0003  5031                  JMP LOWPWR             /YES-HANDLE IT
0004  0000    SAVEAC,       0
0005  0000    SAVEL,        0
0006  0000    PC,           0
0007  0000    AC,           0
0010  0000    LINK,         0
0011  0000    INDEX1,       0                      /INDEX REGISTERS
0012  0000    INDEX2,       0
0013  0000    INDEX3,       0
0014  6401    OTHER1,       TFS                    /IS IT TOF?
0015  5047                  JMP OTHER2             /NO
0016  3004                  DCA SAVEAC             /YES
0017  7010                  RAR
0020  3005                  DCA SAVEL              /SAVE LINK
0021  6406                  TFL                    /READ TOF RESET TOF FLAG
0022  1120                  TAD P2THOU             /ADD ADDRESS OF REGION
0023  7430                  SZL                    /ILLIGAL CHANNEL?
0024  5053                  JMP CONTIN             /YES-REJECT
0025  3130                  DCA HOLD2              /INCREMENT CONTENT
0026  2530                  ISZ I HOLD2            /OF PROPER CHANNEL
0027  5053                  JMP CONTIN             /CONTINUE
0030  5777                  JMP OVRFLO             /CHANNEL OVERFLOW
0031  3007    LOWPWR,       DCA AC                 /SAVE AC
0032  7010                  RAR.
0033  3010                  DCA LINK               /SAVE LINK
0034  1000                  TAD 0000
0035  3006                  DCA PC                 /SAVE PC
0036  1041                  TAD RESTRT             /GET RESTART LOCATION
0037  3000                  DCA 0000               /DEPOSIT IN 0
0040  7402                  HLT
0041  5042    RESTRT,       JMP RESUME
0042  1010    RESUME,       TAD LINK               /GET LINK
0043  7104                  CLL RAL                /RESTORE LINK
0044  1007                  TAD AC                 /GET AC
0045  6001                  ION                    /ENABLE PI
0046  5406                  JMP I PC               /RETURN TO IR.PROGRAM
0047  6042    OTHER2,       TCF                    /IGNORE TELEPRINTER
0050  6031                  KSF                    /IF IN INPUT MODE
0051  5057                  JMP CONTIN+4
0052  5776                  JMP CMMAND             /KEYBOARD
0053  7200    CONTIN,       CLA
0054  1005                  TAD SAVEL              /GET LINK
0055  7104                  CLL RAL                /RESTORE LINK
0056  1004                  TAD SAVEAC             /RESTORE AC
0057  6001                  ION                    /ENABLE PI
0060  5400                  JMP I INTER-2          /EXIT
0061  0000    PRINT1,       0000                   /PRINT SUBROUTINE
0062  6046                  TLS                    /WITHOUT INTERRUPT
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Sample run

The slow chopper facility at the reactor ISPRA-I has been used with a scattering sample of $Ca(OH)_2$. One detector and 256 channels were used ($14_8 \Rightarrow$ DETRNR). The settings on the converter were: Delay = 0; Interval width = 32 μs.
After several hours of data accumulation the keyboard commands

N

D 01 0025 0080

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were given and the first picture was taken (see Fig.1). After an E-command the second picture was taken (see Fig.2). To get a print-out of all channels another D-command was given: D 01 followed by a W-command. The resulting list is given in table 2.

Reference

1)   G.Colombo, N.Coppo, L.Stanchi, Nucl.Instr.Meth. <u>59</u> (1968) 86

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0147    0000    PRODCT,     0000
0150    0000    LSTORE,     0000
0151    0000    WLMARK,     0000
0152    0000    LOMARK,     0000
0153    0000    HIMARK,     0000
0154    0000    WHMARK,     0000
0155    0000    SLMARK,     0000
0156    0000    SLOMRK,     0000
0157    0000    SHIMRK,     0000
0160    0000    SHMARK,     0000
0161    0000    XLMARK,     0000
0162    0000    MINC,       0000
0163    0000    SINC,       0000
0164    0545    READ,       READRT
0165    5014    ON,         JMP OTHER1
0166    5074    OFF,        JMP TTINTR
0167    0746    ADRSC6,     TABLE3+7
0170    0736    ADRSC7,     TABLE3-1
0171    0752    ADRS11,     TABLE3+13
0172    1121    TADMI4,     TAD MINUS4
0173    1124    TADMI2,     TAD MINUS2
0174    0014    DETRNR,     0014



                /TIME OF FLIGHT PROGRAM
                *200
0200    6032    BEGIN,      KCC                 /CLEAR FLAGS
0201    6042                TCF
0202    1245                TAD BELL            /RING BELL
0203    4061                JMS PRINT1
0204    1112                TAD CARRTN          /PRINT CR,LF
0205    4061                JMS PRINT1
0206    1111                TAD LNFEED
0207    4061                JMS PRINT1
0210    4564    CMMAND,     JMS I READ          /GO TO READ COMMAND
0211    1232                TAD ADRSC3          /DECODE IT
0212    3013                DCA INDEX3
0213    1234                TAD TABLE2+1
0214    3134                DCA COUNT1
0215    1246                TAD ADRSC1
0216    3130                DCA HOLD2
0217    1127                TAD HOLD1
0220    1413                TAD I INDEX3
0221    7450                SNA
0222    5227                JMP .+5
0223    2130                ISZ HOLD2
0224    2134                ISZ COUNT1
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0063    6041                    TSF
0064    5063                    JMP .-1
0065    6042                    TCF
0066    7200                    CLA
0067    5461                    JMP I PRINT1
0070    0000    PRNTIR,         0000            /PRINT SUBROUTINE
0071    6046                    TLS             /WITH INTERRUPT
0072    7200                    CLA
0073    5054                    JMP CONTIN+1
0074    6404    TTINTR,         TFC             /CLEAR FLAG OF TOF
0075    3004                    DCA SAVEAC      /SAVE AC
0076    7010                    RAR
0077    3005                    DCA SAVEL       /SAVE LINK
0100    6041                    TSF
0101    5104                    JMP OTHER3
0102    6042                    TCF
0103    5470                    JMP I PRNTIR
0104    6031    OTHER3,         KSF
0105    5053                    JMP CONTIN
0106    5776                    JMP CMMAND
0107    7760    MIN20,          7760
0110    0240    SPACE,          0240
0111    0212    LNFEED,         0212
0112    0215    CARRTN,         0215
0113    0277    QMARK,          0277
0114    7563    MINCR,          7563
0115    7401    MRBOUT,         7401
0116    6000    M2THOU,         6000
0117    1000    P1THOU,         1000
0120    2000    P2THOU,         2000
0121    7774    MINUS4,         7774
0122    0400    P4HUN,          0400
0123    7777    MINUS1,         7777
0124    7776    MINUS2,         7776
0125    5777    MSIZE,          5777
0126    0017    MASK15,         0017
0127    0000    HOLD1,          0000
0130    0000    HOLD2,          0000
0131    0000    HOLD3,          0000
0132    0000    HIGH,           0000
0133    0000    LOW,            0000
0134    0000    COUNT1,         0000
0135    0000    COUNT2,         0000
0136    0000    COUNT3,         0000
0137    0000    COUNT4,         0000
0140    0000    COUNT5,         0000
0141    0000    COUNT6,         0000
0142    0000    COUNT7,         0000
0143    0000    COUNT8,         0000
0144    0000    CONST6,         0000
0145    0000    CONST7,         0000
0146    0000    CONST8,         0000
```

```
0311   1152              TAD LOMARK
0312   3133              DCA LOW
0313   1533              TAD I LOW          /OUTPUT THIS ONE
0314   3133              DCA LOW
0315   4777              JMS PNTDEC
0316   1141              TAD COUNT6
0317   1140              TAD COUNT5         /DONE?
0320   7650              SNA CLA
0321   5776              JMP RE1            /YES
0322   2140              ISZ COUNT5         /NO
0323   2142              ISZ COUNT7         /OUTPUT 10?
0324   5310              JMP GO2            /NO
0325   1112              TAD CARRTN         /YES-TYPE CR,LF
0326   4070              JMS PRNTIR
0327   1111              TAD LNFEED
0330   4070              JMS PRNTIR
0331   5300              JMP GO1            /CONTINUE
0332   4564   ENABLE,    JMS I READ         /ENABLE DATA TAKING
0333   1111              TAD LNFEED
0334   4061              JMS PRINT1
0335   1165              TAD ON
0336   3002              DCA INTER
0337   5053              JMP CONTIN
0340   4564   DSABLE,    JMS I READ         /DISABLE DATA TAKING
0341   1111              TAD LNFEED
0342   4061              JMS PRINT1
0343   1166              TAD OFF
0344   3002              DCA INTER
0345   5053              JMP CONTIN


                         /TIME OF FLIGHT PROGRAM
0376   0400   *400
0377   0661
0400   1112   RE1,       TAD CARRTN
0401   4070              JMS PRNTIR
0402   1111              TAD LNFEED
0403   4070              JMS PRNTIR
0404   5053              JMP CONTIN
0405   1166   OVRFLO,    TAD OFF            /CHANNEL OVERFLOW
0406   3002              DCA INTER          /DISABLE DATA TAKING
0407   1130              TAD HOLD2
0410   1116              TAD M2THOU
0411   3130              DCA HOLD2
0412   7240              CMA CLA
```

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```
0225    5220                JMP .-5
0226    5200                JMP BEGIN           /ERROR-RESTART
0227    1530                TAD I HOLD2
0230    3130                DCA HOLD2           /GO TO PROPER ROUTINE
0231    5530                JMP I HOLD2
0232    0232    ADRSC3,     TABLE2-1            /COMMAND DECODING TABLE
0233    7474    TABLE2,     7474
0234    7766                7766
0235    7764                7764
0236    0003                0003
0237    0007                0007
0240    0013                0013
0241    7755                7755
0242    0013                0013
0243    7770                7770
0244    0011                0011
0245    0207    BELL,       0207
0246    0247    ADRSC1,     TABLE1
0247    1200    TABLE1,     DSPLAY
0250    0340                DSABLE
0251    0600                CLDATA
0252    0261                WRITE
0253    1111                PUNCH
0254    0760                EXPAND
0255    0332                ENABLE
0256    1657                LOAD
0257    1650                UPPER
0260    1641                LOWER
0261    4564    WRITE,      JMS I READ
0262    1166                TAD OFF             /DISABLE DATA TAKING
0263    3002                DCA INTER
0264    3140                DCA COUNT5
0265    1111                TAD LNFEED
0266    4070                JMS PRNTIR
0267    1153                TAD HIMARK
0270    7041                CIA
0271    1152                TAD LOMARK
0272    3141                DCA COUNT6
0273    1121                TAD MINUS4
0274    3144                DCA CONST6
0275    1167                TAD ADRSC6
0276    3145                DCA CONST7
0277    3132                DCA HIGH
0300    1234    GO1,        TAD TABLE2+1        /-10 DECIMAL
0301    3142                DCA COUNT7
0302    1150                TAD LSTORE
0303    7041                CIA
0304    1152                TAD LOMARK
0305    1140                TAD COUNT5
0306    3133                DCA LOW
0307    4777                JMS PNTDEC          /GO TO OUTPUT ROUTINE
0310    1140    GO2,        TAD COUNT5
```

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```
0477   0126              AND MASK15
0500   1147              TAD PRODCT
0501   2134              ISZ COUNT1
0502   7410              SKP
0503   5671              JMP I INPUT4
0504   7104              CLL RAL
0505   3147              DCA PRODCT
0506   1147              TAD PRODCT
0507   7006              RTL
0510   1147              TAD PRODCT
0511   3147              DCA PRODCT
0512   5275              JMP INPUT4+4
0513   0000    INPUT2,   0                  'INPUT 2 DECIMALS
0514   1173              TAD TADMI2
0515   3272              DCA INPUT4+1        /MODIFY FOR 2 DECIMALS
0516   4271              JMS INPUT4
0517   3147              DCA PRODCT
0520   1172              TAD TADMI4          /RESTORE INPUT4
0521   3272              DCA INPUT4+1
0522   5713              JMP I INPUT2
0523   1344    PRFULL,   TAD ADRSC4          /PRINT ''FULL,CR,LF''
0524   3012              DCA INDEX2
0525   1412              TAD I INDEX2
0526   7450              SNA
0527   5332              JMP .+3
0530   4070              JMS PRNTIR
0531   5325              JMP .-4
0532   1165              TAD ON
0533   3002              DCA INTER
0534   5053              JMP CONTIN
0535   0306    TABLE6,   0306
0536   0325              0325
0537   0314              0314
0540   0314              0314
0541   0215              0215
0542   0212              0212
0543   0000              0000
0544   0534    ADRSC4,   TABLE6-1
0545   0000    READRT,   0000               /READ ROUTINE
0546   7200              CLA
0547   6031              KSF
0550   5347              JMP .-1
0551   6036              KRB
0552   3127              DCA HOLD1
0553   1127              TAD HOLD1
0554   4061              JMS PRINT1
0555   1127              TAD HOLD1
0556   1115              TAD MRBOUT          /RUBOUT?
0557   7650              SNA CLA
0560   5362              JMP IPCORR          /YES
0561   5745              JMP I READRT
0562   1172    IPCORR,   TAD TADMI4
0563   3272              DCA INPUT4+1
0564   5775              JMP BEGIN
```

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```
0413    1174            TAD  DETRNR
0414    7640            SZA  CLA
0415    5222            JMP  .+5
0416    7001            IAC
0417    3140            DCA  COUNT5
0420    1130            TAD  HOLD2
0421    5247            JMP  .+26
0422    3133            DCA  LOW
0423    1174            TAD  DETRNR
0424    7110            CLL  RAR
0425    2133            ISZ  LOW
0426    7440            SZA
0427    5224            JMP  .-3
0430    1377            TAD  (-14)
0431    1133            TAD  LOW
0432    3133            DCA  LOW
0433    1133            TAD  LOW
0434    3132            DCA  HIGH
0435    1130            TAD  HOLD2
0436    7110            CLL  RAR
0437    2132            ISZ  HIGH
0440    5236            JMP  .-2
0441    7001            IAC
0442    3140            DCA  COUNT5
0443    7124            STL  RAL
0444    2133            ISZ  LOW
0445    5243            JMP  .-2
0446    0130            AND  HOLD2
0447    3131            DCA  HOLD3
0450    1131    CASEX,  TAD  HOLD3
0451    3133            DCA  LOW
0452    3132            DCA  HIGH
0453    1121            TAD  MINUS4
0454    3144            DCA  CONST6
0455    1167            TAD  ADRSC6
0456    3145            DCA  CONST7
0457    4776            JMS  PNTDEC
0460    1140            TAD  COUNT5
0461    3133            DCA  LOW
0462    3132            DCA  HIGH
0463    1124            TAD  MINUS2
0464    3144            DCA  CONST6
0465    1171            TAD  ADRS11
0466    3145            DCA  CONST7
0467    4776            JMS  PNTDEC
0470    5323            JMP  PRFULL
0471    0000    INPUT4, 0                       /INPUT 4 DECIMALS
0472    1121            TAD  MINUS4
0473    3134            DCA  COUNT1
0474    3147            DCA  PRODCT
0475    4564            JMS I READ
0476    1127            TAD  HOLD1
```

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```
                        /TIME OF FLIGHT PROGRAM
        0575    0200    *600
        0576    0661
        0577    7764
        0600    4564    CLDATA,     JMS I READ      /CLEAR DATA ROUTINE
        0601    1166                TAD OFF         /DISABLE DATA TAKING
        0602    3002                DCA INTER
        0603    1114                TAD MINCR
        0604    1127                TAD HOLD1
        0605    7640                SZA CLA         /IS IT CR?
        0606    5214                JMP .+6         /NO-GO TO INPUT 2 DECIMALS
        0607    7040                CMA
        0610    3154                DCA WHMARK
        0611    1120                TAD P2THOU
        0612    3151                DCA WLMARK
        0613    5217                JMP .+4
        0614    4777                JMS INPUT2
        0615    4776                JMS WMARK
        0616    4564                JMS I READ
        0617    1151                TAD WLMARK
        0620    1123                TAD MINUS1
        0621    3011                DCA INDEX1
        0622    1154                TAD WHMARK
        0623    7040                CMA
        0624    1151                TAD WLMARK
        0625    3134                DCA COUNT1
        0626    3411                DCA I INDEX1
        0627    2134                ISZ COUNT1
        0630    5226                JMP .-2
        0631    5775                JMP RE1
        0632    0000    SHIFTL,     0               /SHIFT LEFT ROUTINE
        0633    7450                SNA
        0634    5254                JMP SHFTRG-2
        0635    7500                SMA
        0636    5243                JMP .+5
        0637    3255                DCA SHFTRG-1
        0640    1257                TAD SHFTRG+1
        0641    3250                DCA .+7
        0642    5247                JMP .+5
        0643    7041                CMA IAC
        0644    3255                DCA SHFTRG-1
        0645    1260                TAD SHFTRG+2
        0646    3250                DCA .+2
        0647    1256                TAD SHFTRG
        0650    0000                0
        0651    2255                ISZ SHFTRG-1
        0652    5250                JMP .-2
        0653    3256                DCA SHFTRG
        0654    5632                JMP I SHIFTL
        0655    0000                0
        0656    0000    SHFTRG,     0
        0657    7110                CLL RAR
```

```
0660    7104              CLL RAL
0661    0000    PNTDEC,   0                      /PRINT DECIMAL
0662    1144              TAD CONST6
0663    3143              DCA COUNT8
0664    1145              TAD CONST7
0665    3012              DCA INDEX2
0666    1412              TAD I INDEX2
0667    3333              DCA HSUB
0670    1412              TAD I INDEX2
0671    3334              DCA LSUB
0672    3336              DCA CHRCTR
0673    4312              JMS ADD
0674    1336              TAD CHRCTR
0675    1357              TAD ZERO
0676    4070              JMS PRNTIR
0677    2143              ISZ COUNT8
0700    5266              JMP .-12
0701    1121              TAD MINUS4
0702    7001              IAC
0703    3143              DCA COUNT8
0704    2143              ISZ COUNT8
0705    7410              SKP
0706    5661              JMP I PNTDEC
0707    1110              TAD SPACE
0710    4070              JMS PRNTIR
0711    5304              JMP .-5
0712    0000    ADD,      0
0713    7100              CLL
0714    1133              TAD LOW
0715    1334              TAD LSUB
0716    3335              DCA TEMPL
0717    7004              RAL
0720    1132              TAD HIGH
0721    1333              TAD HSUB
0722    7420              SNL
0723    5331              JMP .+6
0724    3132              DCA HIGH
0725    1335              TAD TEMPL
0726    3133              DCA LOW
0727    2336              ISZ CHRCTR
0730    5313              JMP ADD+1
0731    7200              CLA
0732    5712              JMP I ADD
0733    0000    HSUB,     0
0734    0000    LSUB,     0
0735    0000    TEMPL,    0
0736    0000    CHRCTR,   0
0737    3166    TABLE3,    3166
0740    4600              4600
0741    7413              7413
0742    6700              6700
0743    7747              7747
```

```
1022   1022   ADRSC8,    TABLE4-1
1023   7764   TABLE4,    7764
1024   0006              0006
1025   0003              0003
1026   0002              0002
1027   1030   ADRSC9,    TABLE5
1030   1034   TABLE5,    CASE12
1031   1051              CASE6
1032   1066              CASE3
1033   1103              CASE1
1034   7040   CASE12,    CMA
1035   1147              TAD PRODCT
1036   7100              CLL
1037   7012              RTR
1040   7012              RTR
1041   7010              RAR
1042   1120              TAD P2THOU
1043   3151              DCA  WLMARK
1044   1151              TAD  WLMARK
1045   1122              TAD P4HUN
1046   1123              TAD MINUS1
1047   3154              DCA  WHMARK
1050   5600              JMP  I  WMARK
1051   7040   CASE6,     CMA
1052   1147              TAD PRODCT
1053   7100              CLL
1054   7012              RTR
1055   7012              RTR
1056   1120              TAD P2THOU
1057   3151              DCA  WLMARK
1060   1122              TAD P4HUN
1061   7004              RAL
1062   1151              TAD  WLMARK
1063   1123              TAD MINUS1
1064   3154              DCA  WHMARK
1065   5600              JMP  I  WMARK
1066   7040   CASE3,     CMA
1067   1147              TAD PRODCT
1070   7100              CLL
1071   7012              RTR
1072   7010              RAR
1073   1120              TAD P2THOU
1074   3151              DCA  WLMARK
1075   1122              TAD P4HUN
1076   7006              RTL
1077   1151              TAD  WLMARK
1100   1123              TAD MINUS1
1101   3154              DCA  WHMARK
1102   5600              JMP  I  WMARK
1103   1120   CASE1,     TAD P2THOU
1104   3151              DCA  WLMARK
1105   1151              TAD  WLMARK
```

```
0744    4540                    4540
0745    7775                    7775
0746    4360                    4360
0747    7777                    7777
0750    6030                    6030
0751    7777                    7777
0752    7634                    7634
0753    7777                    7777
0754    7766                    7766
0755    7777                    7777
0756    7777                    7777
0757    0260    ZERO,           0260
0760    4564    EXPAND,         JMS I READ
0761    1111                    TAD LNFEED
0762    4061                    JMS PRINT1
0763    1152                    TAD LOMARK
0764    3151                    DCA WLMARK
0765    1153                    TAD HIMARK
0766    3154                    DCA WHMARK
0767    5774                    JMP GO3+6


                /TIME OF FLIGHT PROGRAM
0774    1311    *1000
0775    0400
0776    1000
0777    0513
1000    0000    WMARK,          0               /PRODUCES FROM DETRNR AND
1001    1227                    TAD ADRSC9      /PRODCT (WHICH CONTAINS
1002    3131                    DCA HOLD3       /A DETECTOR NUMBER) THE REAL
1003    1222                    TAD ADRSC8      /MEMORY ADDRESS OF FIRST
1004    3013                    DCA INDEX3      /AND LAST CHANNEL CORRESPON
1005    1121                    TAD MINUS4      /TO THAT DETECTOR
1006    3134                    DCA COUNT1
1007    1174                    TAD DETRNR
1010    1413                    TAD I INDEX3
1011    7450                    SNA
1012    5217                    JMP .+5
1013    2131                    ISZ HOLD3
1014    2134                    ISZ COUNT1
1015    5210                    JMP .-5
1016    5777                    JMP BEGIN       /ILLEGAL DETRNR,COMMAND IS
1017    1531                    TAD I HOLD3
1020    3131                    DCA HOLD3
1021    5531                    JMP I HOLD3     /GO TO CASE OR CAS
```

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```
1106    1125              TAD MSIZE
1107    3154              DCA WHMARK
1110    5600              JMP I WMARK
1111    4564    PUNCH,    JMS I READ
1112    1166              TAD OFF
1113    3002              DCA INTER
1114    1111              TAD LNFEED
1115    4070              JMS PRNTIR
1116    4776              JMS LEADIN
1117    1152              TAD LOMARK
1120    3140              DCA COUNT5
1121    1153              TAD HIMARK
1122    7041              CIA
1123    3141              DCA COUNT6
1124    3133              DCA LOW
1125    1140              TAD COUNT5
1126    7120              STL
1127    4775              JMS BINPCH
1130    1540              TAD I COUNT5
1131    7100              CLL
1132    4775              JMS BINPCH
1133    1140              TAD COUNT5
1134    1141              TAD COUNT6
1135    7650              SNA CLA
1136    5341              JMP .+3
1137    2140              ISZ COUNT5
1140    5330              JMP .-10
1141    7100              CLL
1142    1133              TAD LOW
1143    4775              JMS BINPCH
1144    4776              JMS LEADIN
1145    5053              JMP CONTIN
1146    0000    SCALE,    0                      /SET UP SCALE MARKERS
1147    7101              CLL IAC
1150    7006              RTL
1151    6067              DYS
1152    7006              RTL
1153    6067              DYS
1154    7200              CLA
1155    5746              JMP I SCALE
1156    0000    MARK,     0                      /DRAW VERTICAL LINE
1157    1120              TAD P2THOU
1160    7100              CLL
1161    1107              TAD MIN20
1162    7430              SZL
1163    5366              JMP .+3
1164    7200              CLA
1165    5756              JMP I MARK
1166    6067              DYS
1167    5360              JMP .-7
```

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/TIME OF FLIGHT PROGRAM

```
1175    1600    *1200
1176    1627
1177    0200
1200    4564    DSPLAY,   JMS I READ      /READ NEXT CHARACTER
1201    3777              DCA SCALEL
1202    3776              DCA SCALEU
1203    1127              TAD HOLD1
1204    1114              TAD MINCR
1205    7640              SZA CLA         /IS IT CR?
1206    5220              JMP .+12        /NO
1207    1120              TAD P2THOU      /YES-SET LOMARK=2000
1210    3152              DCA LOMARK      /AND HIMARK=7777
1211    1152              TAD LOMARK
1212    3151              DCA WLMARK
1213    7040              CMA
1214    3153              DCA HIMARK
1215    1153              TAD HIMARK
1216    3154              DCA WHMARK
1217    5303              JMP GO3
1220    4775              JMS INPUT2      /INPUT 2 DECIMALS
1221    4774              JMS WMARK       /PRODUCE WHMARK,WLMARK
1222    4564              JMS I READ      /READ NEXT CHARACTER
1223    1127              TAD HOLD1
1224    1114              TAD MINCR
1225    7640              SZA CLA         /IS IT CR?
1226    5234              JMP .+6         /NO
1227    1151              TAD WLMARK      /YES-SET LOMARK=WLMARK
1230    3152              DCA LOMARK      /AND HIMARK=WHMARK
1231    1154              TAD WHMARK
1232    3153              DCA HIMARK
1233    5303              JMP GO3
1234    4773              JMS INPUT4      /INPUT 4 DECIMALS
1235    1151              TAD WLMARK      /SET LOMARK=WLMARK+
1236    3152              DCA LOMARK      /READ-IN VALUE
1237    4564              JMS I READ      /READ NEXT CHARACTER
1240    1127              TAD HOLD1
1241    1114              TAD MINCR
1242    7640              SZA CLA         /IS IT CR?
1243    5247              JMP .+4         /NO
1244    1154              TAD WHMARK      /YES-SET HIMARK=WHMARK
1245    3153              DCA HIMARK
1246    5303              JMP GO3
1247    4773              JMS INPUT4      /INPUT 4 DECIMALS
1250    1151              TAD WLMARK      /SET HIMARK=WLMARK+
1251    3153              DCA HIMARK      /READ-IN VALUE
1252    4564              JMS I READ      /READ NEXT CHARACTER
1253    1127              TAD HOLD1
1254    1114              TAD MINCR
1255    7650              SNA CLA         /IS IT CR?
1256    5303              JMP GO3         /YES
1257    4775              JMS INPUT2      /NO-INPUT 2 DECIMALS
```

```
1260    1151            TAD  WLMARK
1261    3136            DCA  COUNT3
1262   ·1154            TAD  WHMARK
1263    3135            DCA  COUNT2
1264    4774            JMS  WMARK                  /PRODUCE XLMARK
1265    1151            TAD  WLMARK
1266    3161            DCA  XLMARK
1267    1136            TAD  COUNT3
1270    3151            DCA  WLMARK
1271    1135            TAD  COUNT2
1272    3154            DCA  WHMARK
1273    1151            TAD  WLMARK
1274    7041            CIA
1275    1161            TAD  XLMARK
1276    3772            DCA  MDIFF
1277    1771            TAD  MDIFF+2             /SWITCH FOR MULTIPLE
1300    3770            DCA  SWITCH              /DISPLAY
1301    4564            JMS  I READ              /READ NEXT CHARACTER
1302    5305            JMP  .+3
1303    1767    GO3,    TAD  MDIFF+1             /SWITCH FOR SINGLE
1304    3770            DCA  SWITCH              /DISPLAY
1305    1111            TAD  LNFEED
1306    4061            JMS  PRINT1
1307    1151            TAD  WLMARK
1310    3150            DCA  LSTORE
1311    1151            TAD  WLMARK              /CALCULATE SCREEN MARKERS
1312    7041            CIA
1313    1154            TAD  WHMARK
1314    3360            DCA  WHL
1315    3361            DCA  NRS
1316    1360            TAD  WHL
1317    7510            SPA
1320    5324            JMP  .+4
1321    7124            STL  RAL
1322    2361            ISZ  NRS
1323    5317            JMP  .-4
1324    7200            CLA
1325    1361            TAD  NRS
1326    1124            TAD  MINUS2
1327    3361            DCA  NRS
1330    1361            TAD  NRS
1331    7710            SPA  CLA
1332    5344            JMP  .+12
1333    7001            IAC
1334    3162            DCA  MINC
1335    7001            IAC
1336    3766            DCA  SHFTRG
1337    1361            TAD  NRS
1340    4765            JMS  SHIFTL
1341    1766            TAD  SHFTRG
1342    3163            DCA  SINC
1343    5355            JMP  .+12
```

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```
1344   7001              IAC
1345   3163              DCA  SINC
1346   7001              IAC
1347   3766              DCA  SHFTRG
1350   1361              TAD  NRS
1351   7041              CIA
1352   4765              JMS  SHIFTL
1353   1766              TAD  SHFTRG
1354   3162              DCA  MINC
1355   1360              TAD  WHL
1356   3766              DCA  SHFTRG
1357   5764              JMP  1400
1360   0000    WHL,      0
1361   0000    NRS,      0
```

/TIME OF FLIGHT PROGRAM

```
1364   1400    *1400
1365   0632
1366   0656
1367   1542
1370   1507
1371   1543
1372   1541
1373   0471
1374   1000
1375   0513
1376   1656
1377   1655
1400   1777              TAD  NRS
1401   4776              JMS  SHIFTL
1402   1775              TAD  SHFTRG
1403   3774              DCA  WHL
1404   1774              TAD  WHL
1405   7110              CLL  RAR
1406   7040              CMA
1407   1117              TAD  P1THOU
1410   3155              DCA  SLMARK
1411   1155              TAD  SLMARK
1412   1774              TAD  WHL
1413   3160              DCA  SHMARK
1414   1151              TAD  WLMARK
1415   7041              CIA
1416   1152              TAD  LOMARK
1417   3775              DCA  SHFTRG
```

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```
1504    4776                JMS  SHIFTL
1505    1775                TAD  SHFTRG
1506    6067                DYS
1507    0000    SWITCH,     0                  /DISPLAY FUNCTION
1510    1136                TAD  COUNT3        /SWITCH FOR SINGLE/MULTIPLE
1511    1341                TAD  MDIFF         /TAKE 2ND FUNCTION VALUE
1512    3344                DCA  TEMP          /SCALE AND DISPLAY IT
1513    1744                TAD  I TEMP
1514    3775                DCA  SHFTRG
1515    1770                TAD  SCALEU
1516    1124                TAD  MINUS2
1517    4776                JMS  SHIFTL
1520    1775                TAD  SHFTRG
1521    6067                DYS
1522    7200                CLA
1523    1136                TAD  COUNT3
1524    1162                TAD  MINC
1525    3136                DCA  COUNT3.
1526    1135                TAD  COUNT2
1527    1163                TAD  SINC
1530    3135                DCA  COUNT2
1531    2134    GO4,        ISZ  COUNT1
1532    1134                TAD  COUNT1
1533    7041                CIA
1534    7001                IAC
1535    1160                TAD  SHMARK
1536    7650                SNA  CLA
1537    5237                JMP  INDSPL
1540    5245                JMP  INDSPL+6
1541    0000    MDIFF,      0
1542    5322                JMP  SWITCH+13
1543    7200                CLA
1544    0000    TEMP,       0
1545    0077    MASKX,      0077



                        /TIME OF FLIGHT PROGRAM
1570    1656            *1600
1571    1655
1572    1156
1573    1146
1574    1360
1575    0656
1576    9632
1577    1361
```

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```
1420    1777                    TAD  NRS
1421    4776                    JMS  SHIFTL
1422    1775                    TAD  SHFTRG
1423    1155                    TAD  SLMARK
1424    3156                    DCA  SLOMRK
1425    1151                    TAD  WLMARK
1426    7041                    CIA
1427    1153                    TAD  HIMARK
1430    3775                    DCA  SHFTRG
1431    1777                    TAD  NRS
1432    4776                    JMS  SHIFTL
1433    1775                    TAD  SHFTRG
1434    1155                    TAD  SLMARK
1435    3157                    DCA  SHIMRK
1436    6001                    ION
1437    1155    INDSPL,         TAD  SLMARK          /INITIALIZE DISPLAY COUNTERS
1440    3134                    DCA  COUNT1
1441    1134                    TAD  COUNT1
1442    3135                    DCA  COUNT2
1443    1151                    TAD  WLMARK
1444    3136                    DCA  COUNT3
1445    1134                    TAD  COUNT1          /NEW VALUE IN XBUFFER
1446    6053                    DXL
1447    7200                    CLA                  /ZERO IN YBUFFER
1450    6067                    DYS                  /DISPLAY IT
1451    1155                    TAD  SLMARK          /IS SCALE MARKER REQUIRED?
1452    7041                    CIA
1453    1134                    TAD  COUNT1
1454    0345                    AND  MASKX
1455    7041                    CIA
1456    1345                    TAD  MASKX
1457    7650                    SNA  CLA
1460    4773                    JMS  SCALE           /YES-DISPLAY SCALE MARKER
1461    1134                    TAD  COUNT1
1462    7041                    CIA
1463    1135                    TAD  COUNT2
1464    7640                    SZA  CLA
1465    5331                    JMP  GO4             /NO
1466    1134                    TAD  COUNT1          /YES-IS VERT.LINE REQUIRED?
1467    7041                    CIA
1470    1156                    TAD  SLOMRK
1471    7650                    SNA  CLA
1472    4772                    JMS  MARK            /YES-DRAW VERT.LINE
1473    1134            .       TAD  COUNT1          /NO-IS VERT.LINE REQUIRED?
1474    7041                    CIA
1475    1157                    TAD  SHIMRK
1476    7650                    SNA  CLA
1477    4772                    JMS  MARK            /YES-DRAW VERT.LINE
1500    1536                    TAD  I COUNT3        /NO-SCALE FUNCTION
1501    3775                    DCA  SHFTRG
1502    1771                    TAD  SCALEL
1503    1124                    TAD  MINUS2
```

```
1664    3133            DCA LOW
1665    4356            JMS BINRD
1666    1367            TAD MIN200
1667    7650            SNA CLA
1670    5265            JMP .-3
1671    1127            TAD HOLD1
1672    4220            JMS CHECK
1673    7106            CLL RTL
1674    7006            RTL
1675    7006            RTL
1676    3143            DCA COUNT8
1677    4356            JMS BINRD
1700    4220            JMS CHECK
1701    1143            TAD COUNT8
1702    3143            DCA COUNT8
1703    1143            TAD COUNT8
1704    3366            DCA ADDRES
1705    4356    RETURN, JMS BINRD
1706    1367            TAD MIN200
1707    7650            SNA CLA
1710    5340            JMP HALT
1711    1127            TAD HOLD1
1712    4220            JMS CHECK
1713    3370            DCA RDSTR1
1714    1370            TAD RDSTR1
1715    7106            CLL RTL
1716    7006            RTL
1717    7006            RTL
1720    3143            DCA COUNT8
1721    4356            JMS BINRD
1722    4220            JMS CHECK
1723    3371            DCA RDSTR2
1724    1371            TAD RDSTR2
1725    1143            TAD COUNT8
1726    3143            DCA COUNT8
1727    7100            CLL
1730    1143            TAD COUNT8
1731    1766            TAD I ADDRES
1732    7430            SZL
1733    7240            CMA CLA
1734    3766            DCA I ADDRES
1735    2366            ISZ ADDRES
1736    7000            NOP
1737    5305            JMP RETURN
1740    7040    HALT,   CMA
1741    1366            TAD ADDRES
1742    3366            DCA ADDRES
1743    1143            TAD COUNT8
1744    7041            CIA
1745    1766            TAD I ADDRES
1746    3766            DCA I ADDRES
1747    1133            TAD LOW
```

```
1600    0000    BINPCH,     0
1601    3143                DCA  COUNT8
1602    1143                TAD  COUNT8
1603    7012                RTR
1604    7012                RTR
1605    7012                RTR
1606    0217                AND  MASK7
1607    4220                JMS  CHECK
1610    4070                JMS  PRNTIR
1611    1143                TAD  COUNT8
1612    0216                AND  MASK6
1613    4220                JMS  CHECK
1614    4070                JMS  PRNTIR
1615    5600                JMP  I BINPCH
1616    0077    MASK6,      0077
1617    0177    MASK7,      0177
1620    0000    CHECK,      0
1621    3142                DCA  COUNT7
1622    1142                TAD  COUNT7
1623    1133                TAD  LOW
1624    3133                DCA  LOW
1625    1142                TAD  COUNT7
1626    5620                JMP  I CHECK
1627    0000    LEADIN,     0
1630    1240                TAD  COD200
1631    7041                CMA  IAC
1632    3141                DCA  COUNT6
1633    1240                TAD  COD200
1634    4070                JMS  PRNTIR
1635    2141                ISZ  COUNT6
1636    5233                JMP  .-3
1637    5627                JMP  I LEADIN
1640    0200    COD200,     0200
1641    4564    LOWER,      JMS  I READ        /CHANGE SENSITIVITY OF
1642    1127                TAD  HOLD1         /DISPLAY FOR DETECTOR IN
1643    0126                AND  MASK15        /LOWER POSITION
1644    3255                DCA  SCALEL
1645    1110                TAD  SPACE
1646    4061                JMS  PRINT1
1647    5053                JMP  CONTIN
1650    4564    UPPER,      JMS  I READ        /CHANGE SENSITIVITY OF
1651    1127                TAD  HOLD1         /DISPLAY FOR DETECTOR IN
1652    0126                AND  MASK15        /UPPER POSITION
1653    3256                DCA  SCALEU
1654    5245                JMP  LOWER+4
1655    0000    SCALEL,     0
1656    0000    SCALEU,     0
1657    4564    LOAD,       JMS  I READ
1660    1111                TAD  LNFEED
1661    4061                JMS  PRINT1
1662    1166                TAD  OFF
1663    3002                DCA  INTER
```

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Symbol	Value	Symbol	Value	Symbol	Value
AC	0007	HOLD3	0131	P4HUN	0122
ADD	0712	HSUB	0733	QMARK	0113
ADDRES	1766	INDEX1	0011	RDSTR1	1770
ADRSC1	0246	INDEX2	0012	RDSTR2	1771
ADRSC3	0232	INDEX3	0013	READ	0164
ADRSC4	0544	INDSPL	1437	READRT	0545
ADRSC6	0167	INPUT2	0513	RESTRT	0041
ADRSC7	0170	INPUT4	0471	RESUME	0042
ADRSC8	1022	INTER	0002	RETURN	1705
ADRSC9	1027	IPCORR	0562	RE1	0400
ADRS11	0171	LEADIN	1627	SAVEAC	0004
BEGIN	0200	LINK	0010	SAVEL	0005
BELL	0245	LNFEED	0111	SCALE	1146
BINPCH	1600	LOAD	1657	SCALEL	1655
BINRD	1756	LOMARK	0152	SCALEU	1656
CARRTN	0112	LOW	0133	SHFTRG	0656
CASEX	0450	LOWER	1641	SHIFTL	0632
CASE1	1103	LOWPWR	0031	SHIMRK	0157
CASE12	1034	LSTORE	0150	SHMARK	0160
CASE3	1066	LSUB	0734	SINC	0163
CASE6	1051	MARK	1156	SLMARK	0155
CHECK	1620	MASKX	1545	SLOMRK	0156
CHRCTR	0736	MASK15	0126	SPACE	0110
CLDATA	0600	MASK6	1616	SWITCH	1507
CMMAND	0210	MASK7	1617	TABLE1	0247
COD200	1640	MDIFF	1541	TABLE2	0233
CONST6	0144	MINC	0162	TABLE3	0737
CONST7	0145	MINCR	0114	TABLE4	1023
CONST8	0146	MINUS1	0123	TABLE5	1030
CONTIN	0053	MINUS2	0124	TABLE6	0535
COUNT1	0134	MINUS4	0121	TADMI2	0173
COUNT2	0135	MIN20	0107	TADMI4	0172
COUNT3	0136	MIN200	1767	TEMP	1544
COUNT4	0137	MRBOUT	0115	TEMPL	0735
COUNT5	0140	MSIZE	0125	TTINTR	0074
COUNT6	0141	M2THOU	0116	UPPER	1650
COUNT7	0142	NRS	1361	WHL	1360
COUNT8	0143	OFF	0166	WHMARK	0154
DETRNR	0174	ON	0165	WLMARK	0151
DSABLE	0340	OTHER1	0014	WMARK	1000
DSPLAY	1200	OTHER2	0047	WRITE	0261
ENABLE	0332	OTHER3	0104	XLMARK	0161
EXPAND	0760	OVRFLO	0405	ZERO	0757
GO1	0300	PC	0006		
GO2	0310	PNTDEC	0661		
GO3	1303	PRFULL	0523		
GO4	1531	PRINT1	0061		
HALT	1740	PRNTIR	0070		
HIGH	0132	PRODCT	0147		
HIMARK	0153	PUNCH	1111		
HOLD1	0127	P1THOU	0117		
HOLD2	0130	P2THOU	0120		

```
1750   7041              CIA
1751   1370              TAD  RDSTR1
1752   1371              TAD  RDSTR2
1753   1143              TAD  COUNT8
1754   7402              HLT
1755   5777              JMP  RE1
1756   0000     BINRD,   0000
1757   7200              CLA
1760   6031              KSF
1761   5360              JMP  .-1
1762   6036              KRB
1763   3127              DCA  HOLD1
1764   1127              TAD  HOLD1
1765   5756              JMP  I  BINRD
1766   0000     ADDRES,  0000
1767   7600     MIN200,  7600
1770   0000     RDSTR1,  0000
1771   0000     RDSTR2,  0000
1777   0400     $
```

```
/TIME-OF-FLIGHT-COMMANDS
TFS=6401                 /SKIP IF TOF FLAG IS SET
TFL=6406                 /READ TOF AND RESET
TFC=6404                 /CLEAR TOF FLAG
```

Block	Memory locations		Block	Memory locations	
Nr	from	to	Nr	from	to
0	2000	2377	6	5000	5377
1	2400	2777	7	5400	5777
2	3000	3377	8	6000	6377
3	3400	3777	9	6400	6777
4	4000	4377	10	7000	7377
5	4400	4777	11	7400	7777

Table 1

Memory location table

W
```
0000   0000  0002  0004  0007  0005  0004  0004  0002  0008  0007
0010   0002  0004  0007  0001  0008  0002  0004  0003  0009  0002
0020   0002  0006  0001  0001  0005  0008  0021  0027  0038  0046
0030   0064  0103  0104  0139  0153  0165  0136  0159  0211  0241
0040   0317  0323  0322  0303  0272  0227  0219  0173  0158  0123
0050   0126  0101  0093  0085  0075  0078  0072  0075  0094  0111
0060   0129  0115  0131  0130  0146  0126  0132  0125  0108  0089
0070   0093  0097  0065  0071  0067  0059  0058  0052  0047  0041
0080   0050  0033  0039  0035  0051  0034  0030  0028  0026  0030
0090   0030  0026  0033  0036  0031  0030  0024  0023  0047  0093
0100   0253  0358  0415  0482  0450  0443  0448  0443  0480  0455
0110   0495  0507  0550  0477  0456  0494  0452  0487  0517  0517
0120   0536  0520  0487  0510  0498  0494  0514  0518  0493  0485
0130   0468  0459  0400  0457  0382  0384  0420  0379  0374  0350
0140   0372  0321  0317  0314  0309  0317  0309  0269  0234  0251
0150   0239  0263  0231  0237  0223  0203  0205  0197  0160  0174
0160   0159  0162  0144  0152  0152  0163  0125  0110  0120  0124
0170   0152  0121  0104  0133  0106  0115  0119  0083  0092  0074
0180   0056  0071  0061  0062  0050  0048  0061  0051  0043  0048
0190   0050  0029  0049  0028  0037  0036  0041  0034  0027  0031
0200   0031  0031  0021  0019  0023  0016  0025  0013  0017  0015
0210   0021  0011  0017  0011  0013  0014  0016  0012  0015  0015
0220   0013  0015  0012  0008  0011  0007  0009  0008  0005  0015
0230   0007  0006  0005  0011  0010  0003  0005  0004  0005  0007
0240   0009  0011  0006  0007  0003  0004  0008  0009  0013  0007
0250   0007  0006  0004  0007  0008  0008
```
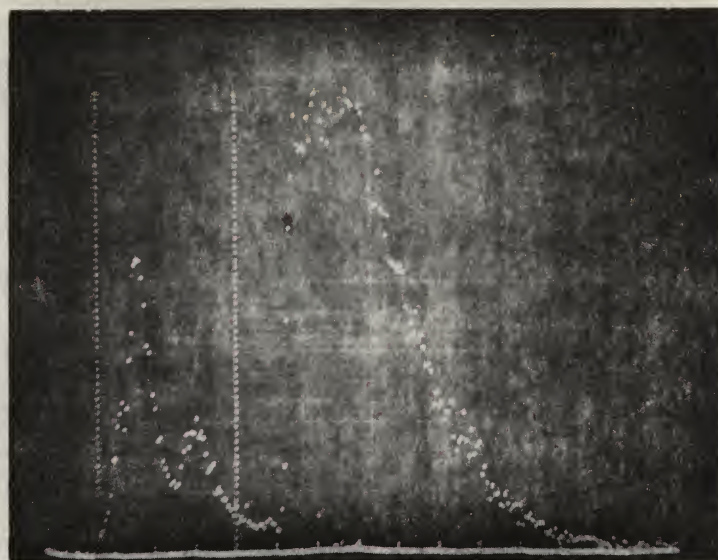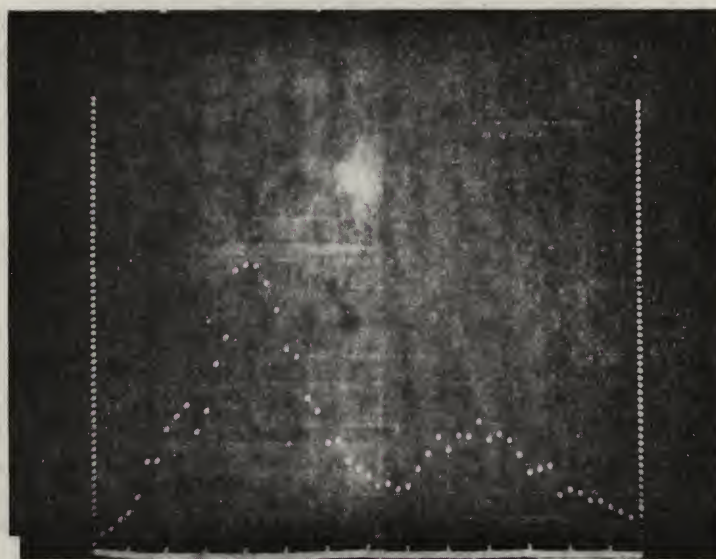
Table 2

Print-out for sample run

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Fig.1
Sample spectrum (see p.19)

Fig.2
Expanded view of sample spectrum

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