COMPUTER PROGRAMS FOR AUTOMATION OF TWO SMALL-ANGLE X-RAY SCATTERING DIFFRACTOMETERS

C. RICHARD DESPER
POLYMER & CHEMISTRY DIVISION

November 1976

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ARMY MATERIALS AND MECHANICS RESEARCH CENTER
Watertown, Massachusetts 02172

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ABSTRACT

SPASTIC 76 is an update of previously reported programs written for a minicomputer to permit data acquisition with a small-angle X-ray diffractometer. SPASTIC denotes System for Programming Angles, Scaler, and Timer by Internal Counting, and indicates the general approach used for automation, involving a simple interface and stepping motor control. The present programs are written for two diffractometers of the Bonse-Hart and the Kratky designs, and run on a PDP-8L computer with 8,192 words of core memory. The various programs include routines for finding the zero position and integral breadth of the primary beam, and for step-scanning through the scattering regions. The latter routine incorporates integrations for the Porod invariant.
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INTRODUCTION

As described in an earlier report, this laboratory has developed a computer-controlled X-ray diffraction instrument denoted as SPASTIC, an acronym for System for Programming Angles, Scaler, and Timer by Internal Counting. The system hardware is based on a PDP-8L computer interfaced to four stepping motors and an X-ray shutter, with an internal data-break scaler for counting X-ray photons, and a timer based on a crystal clock interrupt. The original system was used to control an Advanced Metals Research Model 6-220 Small Angle X-ray Scattering Diffractometer, using motor 1 for the 2θ and motor 2 for the attenuator wheel. Software was developed at the time of the previous report to perform simple control and data-taking operations, accessing the hardware through a modification of the FOCAL language interpreter, denoted SPASTIC 71.

The present report is an update prompted by several developments in the interim: (a) the addition of a Kratky-type small-angle X-ray scattering diffractometer and (b) expansion of the computer memory from 4,096 to 8,192 words, allowing for more complicated programming. The 2θ drive for the Kratky diffractometer has been assigned stepping motor number 3, while number 4 has been allocated to the Norelco wide-angle diffractometer. Software for the latter has not been implemented at this time, but extensive programs have been developed for the Advanced Metals Research (AMR) and Kratky diffractometers. At present, however, the system can control only one diffractometer at a time. The instrument to be used is selected by connecting cables from the computer interface to the appropriate shutter control and X-ray photon pulse jacks.

SPASTIC-76 INTERPRETER

Concurrent with the hardware changes, improvements have been made in the basic machine-language software, now called SPASTIC 76. The hardware functions have been given new names which more readily denote the operation each function performs, and which eliminate ambiguities in the earlier language (FADC, FEXP, FRAN) between SPASTIC control functions and conventional FOCAL functions. In addition, the LIBRARY command has been restored for flexible operation with the mass-storage disk, while the FSIN and FCOS functions have been dropped. The assembler language printout for the SPASTIC 76 interpreter is given in the Appendix.

The corresponding names for the SPASTIC functions in the 1971 and 1976 versions are summarized in Table 1. The actual operations performed by the six controlling functions, listed in detail in Table 2, have not changed in the interim, but the error codes (Table 3) have changed, since these depend upon the core address from which the error routine is called. One new error code has been added in SPASTIC 76: Code 19.72 indicates that one of the arguments of FSET exceeds 2^23, or 8,288,608. An undetected overflow of this type would result in erroneous scaler or timer readings in SPASTIC 71.

Table 1. EQUIVALENT CONTROL FUNCTIONS IN SPASTIC 71 AND SPASTIC 76

<table>
<thead>
<tr>
<th>SPASTIC 71</th>
<th>SPASTIC 76</th>
<th>Function</th>
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<tbody>
<tr>
<td>FADC</td>
<td>FORV</td>
<td>Drive stepping motors</td>
</tr>
<tr>
<td>FDOK</td>
<td>FSET</td>
<td>Set timer limit, scaler limit,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>motor speed</td>
</tr>
<tr>
<td>FOIX</td>
<td>FOPR</td>
<td>Perform one of six possible</td>
</tr>
<tr>
<td></td>
<td></td>
<td>operations</td>
</tr>
<tr>
<td>FEXP</td>
<td>FTIM</td>
<td>Run timer/scaler to limit value</td>
</tr>
<tr>
<td>FRAN</td>
<td>FSOL</td>
<td>Operate shutter solenoid</td>
</tr>
<tr>
<td>FANG</td>
<td>FAND</td>
<td>Logical AND</td>
</tr>
</tbody>
</table>

Table 2. SPASTIC 76 CONTROL FUNCTIONS

1. FORV (A1, A2, A3, A4)
   - Initiate stepping motor drives. A1 through A4 are the number of steps for motors 1 through 4. Zero arguments are ignored and the argument list may be shortened.

2. FSET (TL, SL, MI)
   - Change timer and scaler limits and motor pulse interval. TL is the timer limit in clock units; SL is the scaler limit in counts; and MI is the motor pulse interval in clock units. Negative arguments are illegal. Zero arguments are ignored and the argument list may be shortened. Maximum value of any argument is 2^32, or 4,294,967,296.
   - The values in effect at load time are:
     - TL = 1,228,800 clock units (4096 sec)
     - SL = 1000 counts
     - MI = 1 clock unit (speed = 300 steps/sec)

3. FOPR (ARG)
   - Six options:
     - ARG = 0 Read scaler and timer into FOCAL variables 5' and T'
     - ARG = 1 Stop scaler and timer, then read into 5' and T'
     - ARG = 2 Reset and start scaler and timer.
     - ARG = 3 Return timer run status. FOPR is zero if the timer is running, positive if stopped, negative if a high count rate was detected. ARG = 0, 1, or 2 also returns timer run status.
     - ARG = 4 Return motor status, an integer 0 to 15. All motors stopped = 0; motor 1, 2, 3, or 4 running contributes 1, 2, 4, or 8 respectively.
     - ARG = 5 Stop all motors. Return motor status = 0.

4. FTIM (O)
   - Reset, start, and run scaler/timer to count or time limit. Count and time are read into 5' and T', and the timer status is returned (see FOPR, ARG = 3).

5. FSOL (ARG)
   - ARG = 0 Close solenoid, disable scaler, and clear high count rate condition.
   - ARG = 1 Open solenoid, enable scaler, and enable clock for high count rate protection.
   - ARG = 2 Return solenoid status, 0 or 1.

6. FAND (N1, N2,...)
   - Return the logical AND of integers N1 and N2. Not presently used, but will facilitate the independent control of several motors in conjunction with FOPR (4).

Table 3. SPASTIC 76 ERROR CODES

<table>
<thead>
<tr>
<th>Code</th>
<th>Meaning</th>
</tr>
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<tbody>
<tr>
<td>08.47</td>
<td>Too many function arguments, or unmatched</td>
</tr>
<tr>
<td></td>
<td>parentheses</td>
</tr>
<tr>
<td>19.72</td>
<td>Argument of FSET exceeds 2^32</td>
</tr>
<tr>
<td>19.75</td>
<td>Argument of FSET is negative</td>
</tr>
<tr>
<td>19.9</td>
<td>Attempt to change count or time limit with</td>
</tr>
<tr>
<td></td>
<td>timer running</td>
</tr>
<tr>
<td>19.13</td>
<td>Argument of FOPR outside range 0 to 5</td>
</tr>
<tr>
<td>20.03</td>
<td>Timer restart with high count rate uncleared</td>
</tr>
</tbody>
</table>

ZEROING PROGRAMS

One of the more convenient aspects of computer control for a small-angle X-ray scattering diffractometer is the ability to "zero" the instrument; i.e., to scan through the primary beam and find the true zero position in 20. Naturally, the beam must be considerably weakened to execute these programs, since the full power of the primary beam would damage the X-ray detector. This is accomplished by turning the attenuator wheel to the "3" position for the AMR instrument, and by inserting a special lead filter in the Kratky diffractometer. In the latter case, since the beam is not monochromatic, insertion of the filter changes the wavelength spectrum reaching the detector, selectively filtering out some of the characteristic radiation at 1.5418 angstroms while passing more of the white radiation in the 0.3 to 0.8 angstrom range.

To avoid the electronic rejection of the latter, which often exceeds the characteristic radiation intensity under such circumstances, it is recommended that the radiation analyzer be set to integral mode to accept both types of radiation. The computer types out a reminder to this effect.

The zeroing programs for the AMR and Kratky diffractometers, written in the SPASTIC 76 variation of the FOCAL language, are given in Tables 4 and 5. Several improvements have been made on the SPASTIC 71 zeroing program: (a) the program prints out the entire intensity profile rather than the peak intensity only; (b) the zero determined is a true mathematical zero, defined as the center of gravity of the beam rather than the position of...
Table 4. MR ZEROING PROGRAM

<table>
<thead>
<tr>
<th>Line</th>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>10-10</td>
<td>E</td>
<td></td>
</tr>
<tr>
<td>10-15</td>
<td>T</td>
<td>&quot;AM ZEROING: TH 14 SECONDS&quot;11S =FPOA(5)1S ML=1B1S DL=5</td>
</tr>
<tr>
<td>10-20</td>
<td>A</td>
<td>&quot;AT IS&quot;=UPCL 31IS 4C=31S AR=400*(4)16ID 1610</td>
</tr>
<tr>
<td>10-20</td>
<td>P</td>
<td>&quot;PdC-M (SPASTIC.76 - 10.10 E)</td>
</tr>
<tr>
<td>10-40</td>
<td>S</td>
<td>&quot;PdC-M.11S =FPOA(5)1S ML=1B1S DL=5</td>
</tr>
<tr>
<td>10-50</td>
<td>S</td>
<td>&quot;SET(TE)13.71D 1911 (TH-SI)18-40IS U=SET(TE)18-36E</td>
</tr>
<tr>
<td>12-20</td>
<td>T</td>
<td>&quot;FPOA(5)1S IS=1B1S DL=96.6I 10.10E</td>
</tr>
</tbody>
</table>

Table 5. KRAUTKY ZEROING PROGRAM

<table>
<thead>
<tr>
<th>Line</th>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>10-10</td>
<td>E</td>
<td></td>
</tr>
<tr>
<td>10-15</td>
<td>T</td>
<td>&quot;AM ZEROING: ANALYZE TO INTRAMAL&quot;11S =FPOA(5)1S ML=4</td>
</tr>
<tr>
<td>10-20</td>
<td>T</td>
<td>&quot;PdC-M.11S =FPOA(5)1S ML=4</td>
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<tr>
<td>10-40</td>
<td>S</td>
<td>&quot;PdC-M.11S =FPOA(5)1S ML=4</td>
</tr>
<tr>
<td>10-50</td>
<td>S</td>
<td>&quot;SET(TE)13.71D 1911 (TH-SI)18-40IS U=SET(36E.36E)</td>
</tr>
<tr>
<td>12-20</td>
<td>T</td>
<td>&quot;FPOA(5)1S IS=1B1S DL=96.6I 10.10E</td>
</tr>
</tbody>
</table>

Table 6. KRATKY ZEROING PROGRAM

<table>
<thead>
<tr>
<th>Line</th>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>10-10</td>
<td>E</td>
<td></td>
</tr>
<tr>
<td>10-15</td>
<td>T</td>
<td>&quot;AM ZEROING: ANALYZE TO INTRAMAL&quot;11S =FPOA(5)1S ML=4</td>
</tr>
<tr>
<td>10-20</td>
<td>T</td>
<td>&quot;PdC-M.11S =FPOA(5)1S ML=4</td>
</tr>
<tr>
<td>10-40</td>
<td>S</td>
<td>&quot;PdC-M.11S =FPOA(5)1S ML=4</td>
</tr>
<tr>
<td>10-50</td>
<td>S</td>
<td>&quot;SET(TE)13.71D 1911 (TH-SI)18-40IS U=SET(36E.36E)</td>
</tr>
<tr>
<td>12-20</td>
<td>T</td>
<td>&quot;FPOA(5)1S IS=1B1S DL=96.6I 10.10E</td>
</tr>
</tbody>
</table>

...
maximum intensity, and (c) the zeroing process is repeated if either end of intensity profile exceeds 5% of the maximum intensity, indicating that too much of the beam is outside the range of observation. As a by-product, the zeroing programs yield the integral breadth of the intensity profile. This is defined as the ratio of the integrated intensity to the maximum intensity; i.e., it is the width of a hypothetical rectangle whose height is the maximum intensity and whose area is equal to the integrated intensity.

Sample printouts from the execution of the two zeroing programs are given in Tables 6 and 7. For the AMR instrument (Table 6) the interval between data points in the profile determination is fixed at 0.5 second of arc. Since the AMR diffractometer has a fixed integral breadth of approximately 10 seconds when properly aligned, use of the 0.5-second interval should yield an acceptable center of gravity with negligible tails within two trials. If not, the interval is successively raised to 1, 2, and 4 seconds of arc before giving up the zeroing attempt. For the Kratky instrument (Table 7) the interval between data points is set to 1/20th of the sum of the input values of the entrance and receiving slit widths. Since the expected breadth of the primary beam is approximately the sum of the two slit widths, this interval gives a good measure of the beam profile.

STEP-SCAN PROGRAMS

The earlier report1 included a simple step-scan program for use with the AMR diffractometer, capable of taking intensity measurements at a series of 2θ values with variable spacing along the 2θ axis. Our experience in using this program has resulted in a number of modifications which have improved the operation of the system. The modifications are as follows:

(A) Antibacklash--When 2θ is driven to a lower numerical value, the programs pass the final destination, then reverse the motor direction for setting the angle. Since the angle is therefore always set with the motor driving in the positive direction, the backlash is taken out of the drive train.

(B) Rezeroing--At the end of a step-scan execution, the shutter is closed and the 2θ angle is set to zero. Since stepping motor control does not give absolute feedback of the angle value, it is imperative to know the initial value of 2θ when starting a new program. This feature makes it easy to remember: if the last program terminated normally, 2θ was left as zero. For the AMR instrument, the attenuator is also left at #3 position, the correct value for 2θ equals zero.

(C) Angle Units--The present step-scan programs allow for different units for defining the 2θ angle. For the AMR diffractometer, two versions of the programs are maintained with 2θ defined in seconds and in minutes. For the Kratky diffractometer, the appropriate unit is microns of elevation of the receiving slit, since this variable is fixed by the motor drive. The corresponding angle depends upon the distance set between the 2θ pivot and the receiving slit. The distance commonly used in this laboratory is 229.2 mm, chosen so that 1° in 2θ corresponds to 4000 microns of elevation. Changing angle units is effected by defining a multiplier at the start of the program, which is the number of motor steps per unit of angle.
### Table 6. EXECUTION OF AMR ZEROING PROGRAM

<table>
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<tr>
<th>SECONDS</th>
<th>CTS/SEC</th>
<th>SECONDS</th>
<th>CTS/SEC</th>
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<th>CTS/SEC</th>
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<td>MAX= 4740 CTS/SEC= 7364 CTS/SEC</td>
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### Table 7. EXECUTION OF KRATKY ZEROING PROGRAM

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<th>MICRONS CTS/SEC</th>
<th>MICRONS CTS/SEC</th>
<th>MICRONS CTS/SEC</th>
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</table>

5
(D) Attenuator Programming--For the AMR diffractometer, changes in the attenuator position have been incorporated into the step-scan programs.

(E) Multiple Scanning--One program has been written for repeated multiple scans using the Kratky camera, to average out possible fluctuations in primary beam intensity with time. Improved control over the cooling water flow rate in the X-ray tube has obviated the need for this program, but it is included for completeness.

(F) Integration for the Porod Invariant--Some minor additions to the programs have made it possible to calculate the Porod invariant $\xi_m$ as a by-product of the step-scan program. The expression used to calculate $\xi_m$ is that suitable for use with experimental (smeared) intensity $\bar{y}(m)$ obtained with long slits:

$$\xi_m = \int_0^\infty m \bar{y}(m) \, dm$$

where $m$ is the elevation variable in microns as defined in the Kratky instrument. The value of $\xi_m$ calculated by the program is, of course, an approximation based on the use of the trapezoid rule and a finite range of integration. Where a background determination is made, the appropriate value of $\xi_m$ is the difference in the two integrals. In the case of the AMR diffractometer, the angle units are different, but the units of the invariant are printed out along with its numerical value in each case. Also, it is appropriate to point out that there is little experience with the present programs, and that asymptotic forms of the intensity curve are often used in the high and low end of the intensity curve to improve accuracy.

The step-scan programs for the AMR diffractometer are listed in Tables 8 and 9 for 20 defined in terms of seconds or minutes of arc. The step-scan program for the Kratky diffractometer is listed in Table 10, while the multiple step-scan program for this instrument appears in Table 11.

For comparison, step-scans were run on the same sample on both the AMR and Kratky diffractometers. The sample chosen was a polypropylene fiber in the form of a mat of parallel yarns of such a thickness as to attenuate the AMR primary beam by a factor 0.513. The data obtained using the two instruments are given in Tables 12 and 13. The printout is somewhat self-explanatory, keeping in mind that input data always follows a colon, while output data follows an equal sign. The abbreviations used in the printout are: AT, attenuator setting; CT LMT, count limit; CTS, counts; DL, interval in 20; TH, 20; and TM LMT, time limit. In each case data is taken closely spaced at the lower 20 values and more widely spaced at the higher values. The diffraction maximum occurs in both sets of data at $20 = 0.6^\circ$ (36 minutes and 2400 microns for the two instruments) corresponding to a Bragg spacing of approximately 150 angstroms. The intensity at the diffraction maximum is higher by a factor of 33 for the Kratky diffractometer, which is in agreement with the ratio of 31 for the integral breadths of the primary beams of the Kratky camera.

Table 8. AMR STEP-SCAN PROGRAM, ANGLE IN SECONDS

<table>
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<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>02:04</td>
<td>S $=FSOL(0)IT IT /<em>SS; TH IV SECUNOS</em>/11S ML=10</td>
</tr>
<tr>
<td>02:06</td>
<td>A &quot;TH IS&quot;,TC:&quot;AT IS&quot;,&quot;AC!&quot;</td>
</tr>
<tr>
<td>02:10</td>
<td>A &quot;CT LMT&quot;,AC:&quot;TM LMT&quot;,MS!</td>
</tr>
<tr>
<td>02:11</td>
<td>S MT=K4380</td>
</tr>
<tr>
<td>02:38</td>
<td>S IFSET(AT,NC 111) S 1=0</td>
</tr>
<tr>
<td>02:30</td>
<td>TYPF &quot;DATA PTS&quot;</td>
</tr>
<tr>
<td>02:54</td>
<td>S I=1-1</td>
</tr>
<tr>
<td>02:56</td>
<td>A &quot;TH&quot;,AT(I),&quot;AT&quot;,AT(I),&quot;DL&quot;,DL(I)</td>
</tr>
<tr>
<td>02:08</td>
<td>I DDL(1) 2+56.3+09.2+54</td>
</tr>
<tr>
<td>03:09</td>
<td>S AT(1+3)S AL(TH(I+1)-TC)+MLIS I+8IS QM=8IS TL+TH(I+1)S AL+AT(I)</td>
</tr>
<tr>
<td>03:14</td>
<td>D 5+413 TC+TH(I+1) (DL(I+1))3+53.5+50</td>
</tr>
<tr>
<td>03:25</td>
<td>D 615 5S TC+TC+DL(I+1) US=FSOQ(DL(I+1))</td>
</tr>
<tr>
<td>03:27</td>
<td>S U=TH(I+1)-TC&quot;+AC+1I (-U)3.45</td>
</tr>
<tr>
<td>03:40</td>
<td>S AL+TC+DL(I)+MLIS TC+TH(I+1)I D 615 SIG 3.18</td>
</tr>
<tr>
<td>03:45</td>
<td>S AL+TC+MLIS TC+FSOQ(0) I D 615 SIG 3.18</td>
</tr>
<tr>
<td>05:01</td>
<td>S $=FOPR(4)I1 (-U)3.5IS US=FSOL(0)I1 (-U)3.50</td>
</tr>
<tr>
<td>05:06</td>
<td>S $=FOPR(3)I1 (1)5+58.5+60</td>
</tr>
<tr>
<td>05:06</td>
<td>S $=FOPR(3)I1 (1)5+58.5+60</td>
</tr>
<tr>
<td>05:10</td>
<td>T 4+54+60* 3SC 300 C/S, PXK AT&quot;$S=51US QM=51US TL+TC</td>
</tr>
<tr>
<td>05:20</td>
<td>S AT+TH(I+1)+TC+DL(I)+MLIS TC+TH(I+1)I D 615 SIG 3.18</td>
</tr>
<tr>
<td>05:40</td>
<td>T 6+50+60* 11&quot;TC+TC+I1 AT&quot;&quot;AC&quot;+66&quot; CTS&quot;S</td>
</tr>
<tr>
<td>05:30</td>
<td>T 4+54+60* 3SC 300 SI+SI+TI1 US=FSOL(0)+TC+DL(I)+TC+TL+Y</td>
</tr>
<tr>
<td>05:50</td>
<td>1 11,KS CT RATE&quot;,111 S US=FSOL(0)I</td>
</tr>
<tr>
<td>06:05</td>
<td>S AQ=AM4(AT(I)-AC)615 AC=AT(I)</td>
</tr>
<tr>
<td>06:10</td>
<td>S $=FOPR(4)S I (-U)3.60</td>
</tr>
<tr>
<td>06:15</td>
<td>I (-A)16.39.6+38</td>
</tr>
<tr>
<td>06:30</td>
<td>S UsFDHV(A1)A1=8IS AQ=8IS AQ=AI+100IS 6.10</td>
</tr>
<tr>
<td>06:30</td>
<td>S UsFDHV(A1)A1=8IS AQ=8IS AQ=AI</td>
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</table>

Table 9. AMR STEP-SCAN PROGRAM, ANGLE IN MINUTES

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<tr>
<td>02:10</td>
<td>A &quot;CT LMT&quot;,AC:&quot;TM LMT&quot;,MS!</td>
</tr>
<tr>
<td>02:11</td>
<td>S AT=K4380</td>
</tr>
<tr>
<td>02:08</td>
<td>S IFSET(AT,NC 111) S 1=0</td>
</tr>
<tr>
<td>02:30</td>
<td>TYPF &quot;DATA PTS&quot;</td>
</tr>
<tr>
<td>02:54</td>
<td>S I=1-1</td>
</tr>
<tr>
<td>02:56</td>
<td>A &quot;TH&quot;,TH(I),&quot;AT&quot;,AT(I),&quot;DL&quot;,DL(I)</td>
</tr>
<tr>
<td>02:08</td>
<td>I DDL(1) 2+56.3+09.2+54</td>
</tr>
<tr>
<td>03:09</td>
<td>S AT(1+3)S AL(TH(I+1)-TC)+MLIS I+8IS QM=8IS TL+TH(I+1)S AL+AT(I)</td>
</tr>
<tr>
<td>03:14</td>
<td>D 5+413 TC+TH(I+1) (DL(I+1))3+53.5+50</td>
</tr>
<tr>
<td>03:25</td>
<td>D 615 5S TC+TC+DL(I) US=FSOQ(DL(I))</td>
</tr>
<tr>
<td>03:27</td>
<td>S U=TH(I+1)-TC&quot;+AC+1I (-U)3.45</td>
</tr>
<tr>
<td>03:40</td>
<td>S AL+TC+DL(I)+MLIS TC+TH(I+1)I D 615 SIG 3.18</td>
</tr>
<tr>
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<td>S AL+TC+MLIS TC+FSOQ(0) I D 615 SIG 3.18</td>
</tr>
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</tr>
<tr>
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<td>S $=FOPR(3)I1 (1)5+58.5+60</td>
</tr>
<tr>
<td>05:06</td>
<td>S $=FOPR(3)I1 (1)5+58.5+60</td>
</tr>
<tr>
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<td>T 4+54+60* 3SC 300 C/S, PXK AT&quot;$S=51US QM=51US TL+TC</td>
</tr>
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<td>1 11,KS CT RATE&quot;,111 S US=FSOL(0)I</td>
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<td>S AQ=AM4(AT(I)-AC)615 AC=AT(I)</td>
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<td>06:10</td>
<td>S $=FOPR(4)S I (-U)3.60</td>
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<tr>
<td>06:15</td>
<td>I (-A)16.39.6+38</td>
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<tr>
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<td>S UsFDHV(A1)A1=8IS AQ=8IS AQ=AI+100IS 6.10</td>
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### Table 10. KRATKY STEP-SCAN PROGRAM, ANGLE IN MICRONS

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<td>A &quot;=K&lt;mRT TH&quot;IC!</td>
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<td>S U=FSET((0,1)+FUPH(1))1S 1=11 &quot;DATA PES&quot;</td>
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<td>00.54</td>
<td>S I=1</td>
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<td>00.56</td>
<td>A 1=TH(1)+&quot;DLC&quot;</td>
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<tr>
<td>00.60</td>
<td>I (DL(1)) 2,3,4,5,6,7,8,9,34</td>
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<tr>
<td>03.09</td>
<td>S A1=TH(1)-TH(1) ID 1=015 QM=654 TL=TH(1)ID 6</td>
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<tr>
<td>03.10</td>
<td>I (-FUPH(1))</td>
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<tr>
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<td>T &quot;SET ANALYSIS TO DIFFERENTIAL&quot;</td>
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<td>03.12</td>
<td>T &quot;USE NICKEL FILTER&quot;!!! S U=FPSOLO(1)</td>
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<td>03.13</td>
<td>A &quot;CT LAT&quot;,AC,&quot;MT LAT&quot;,MS,1S AT=143=33</td>
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<td>03.14</td>
<td>I (FUPH(3))+SBS IS=FSET(CT,MC)</td>
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<tr>
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<td>D 2=SBS T=TH(1)+GST=ATTENUATION FILTER</td>
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<td>D 6ID SII (DL(1))=5,6,7,8</td>
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<tr>
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<td>S T=CTCUL(1)+IS=FPOSQ(1)</td>
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<tr>
<td>03.27</td>
<td>S U=FSET(1)+TC=1E=011 (-I)3.43</td>
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<tr>
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<td>S A1=TH(1)+TDCUL(1)+MLU 3,16</td>
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<tr>
<td>03.45</td>
<td>S A1=DL(1)+MLU 3,16</td>
</tr>
<tr>
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<td>S A1=TCMULS TO=FPOSQ(1)16 IT &quot;QM=QM&quot; M QM C=5</td>
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<td>S U=FPOSQ(1)11 I (U)3.01</td>
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</tr>
<tr>
<td>05.06</td>
<td>S A1=TH(1)+TDCUL(1)+IS=MLU 3,16</td>
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<td>05.08</td>
<td>A &quot;CT LAT&quot;,AC,&quot;MT LAT&quot;,MS,1S AT=143=33</td>
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<td>I (-K&lt;mRT TH&quot;IC!</td>
</tr>
<tr>
<td>05.24</td>
<td>A &quot;CT LAT&quot;,AC,&quot;MT LAT&quot;,MS,1S AT=143=33</td>
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<td>S T=CTCUL(1)+IS=FPOSQ(1)</td>
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<tr>
<td>05.40</td>
<td>I 46.02 S TT&quot;SBS TL=CUL(SL=SIII</td>
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<tr>
<td>05.43</td>
<td>S IT=TC HATE&quot;111&quot; S U=FPOSQ(1)</td>
</tr>
<tr>
<td>06.10</td>
<td>S U=FPOSQ(1)11 (-I)3.60</td>
</tr>
<tr>
<td>06.10</td>
<td>I (-AI=+30.630</td>
</tr>
<tr>
<td>06.20</td>
<td>I U=SFQ(0)+FENUO(0)+AI=200</td>
</tr>
<tr>
<td>06.30</td>
<td>I U=SFQ(0)+FENUO(0)+AI=200</td>
</tr>
<tr>
<td>06.30</td>
<td>I U=SFQ(0)+FENUO(0)+AI=200</td>
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### Table 11. KRATKY MULTIPLE STEP-SCAN PROGRAM, ANGLE IN MICRONS

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<th>Description</th>
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<tbody>
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<td>05.04</td>
<td>A &quot;CT LAT&quot;,AC,&quot;MT LAT&quot;,MS,1S AT=143=33</td>
</tr>
<tr>
<td>05.06</td>
<td>S A1=TH(1)+TDCUL(1)+IS=MLU 3,16</td>
</tr>
<tr>
<td>00.58</td>
<td>A &quot;CT LAT&quot;,AC,&quot;MT LAT&quot;,MS,1S AT=143=33</td>
</tr>
<tr>
<td>05.30</td>
<td>S T=CTCUL(1)+IS=FPOSQ(1)</td>
</tr>
<tr>
<td>05.40</td>
<td>I 46.02 S TT&quot;SBS TL=CUL(SL=SIII</td>
</tr>
<tr>
<td>05.43</td>
<td>S IT=TC HATE&quot;111&quot; S U=FPOSQ(1)</td>
</tr>
<tr>
<td>06.10</td>
<td>S U=FPOSQ(1)11 (-I)3.60</td>
</tr>
<tr>
<td>06.10</td>
<td>I (-AI=+30.630</td>
</tr>
<tr>
<td>06.20</td>
<td>I U=SFQ(0)+FENUO(0)+AI=200</td>
</tr>
<tr>
<td>06.30</td>
<td>I U=SFQ(0)+FENUO(0)+AI=200</td>
</tr>
</tbody>
</table>

8
the two instruments as given in Tables 6 and 7. The lower resolution of the Kratky instrument using the present slit settings allows for much higher levels of diffracted beam intensity. The price that one pays for this intensity is in terms of the minimum angle at which one can take useful data, which is 500 microns, or 0.125°, for the Kratky diffractometer. The data on the AMR instrument starts at 5 minutes, or 0.083°, and could well start much lower. In all fairness, however, it must be stated that the Kratky diffractometer is capable of the same resolution at the AMR instrument if finer slits and a longer working distance are used. The present coarse resolution conditions are deliberately chosen to enhance intensity at the expense of resolution.

As a final demonstration, the multiple step-scan program was executed. A step-scan similar to that of Table 13 was executed ten times. Since the entire intensity data generated is rather voluminous, only a summary is given in Table 14, in the form of the Porod invariant for the ten scans. Any long-term drift in the primary beam intensity would appear as a corresponding change in the two instruments as given in Tables 6 and 7. The lower resolution of the Kratky instrument using the present slit settings allows for much higher levels of diffracted beam intensity. The price that one pays for this intensity is in terms of the minimum angle at which one can take useful data, which is 500 microns, or 0.125°, for the Kratky diffractometer. The data on the AMR instrument starts at 5 minutes, or 0.083°, and could well start much lower. In all fairness, however, it must be stated that the Kratky diffractometer is capable of the same resolution at the AMR instrument if finer slits and a longer working distance are used. The present coarse resolution conditions are deliberately chosen to enhance intensity at the expense of resolution.

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APPENDIX. PALD ASSEMBLY OF SPASTIC 76

S+P+A+S+T+I+C - TAPE 1 - 19 FEB 1976

PSIN AND FCOS DROPPED; LIBRARY COMMAND ALLOWED

SYSTEM FOR PROGRAMMING ANGLES, SCALAR, AND TIMER

BY INTERVAL COUNTING

OVERLAY FOR FOCAL, 1969 FOR XRAY SCATTERING EXPERIMENTS

RICHARD DESPEN, AMMOC, WATERTOWN, MASS.

COMPATIBLE WITH FOCAL 69

...DO NOT USE INIT...

A WORD OVERLAY CAN BE USED; LOAD BA SPASTIC

A4 OVERLAY SHOULD BE USEABLE; LOAD BA SPASTIC

FOCAL FLOATING POINT OPERATIONS

...CAUTION...

SOME OF THESE DIFFER FROM STANDARD

FLOATING POINT OPERATIONS

.........NOTE......... PALD DOES NOT RECOGNIZE FIXU R

USE PAL III INSTEAD OR DELETE FIX U R, SINCE

FIXTAB WILL TAKE CARE OF IT IN PALD

FGET=0000
FADD=1000
FSUB=3000
FDIV=3000
FMUL=4000
FPUS=5000
FPUI=6000

THE ABOVE 7 SYMBOLS REQUIRE FIXU R FOR PAL III

FVOH=7000
FFXT=0000

/HARDWARE IOT'S

SNCF=6311/SAP IF NO CLOCK FLAG
CCF=6312/CLEAR CLOCK FLAG, ENABLE CLOCK
DSCK=6314/DISABLE CLOCK
DSCF=6316/CLEAR CLOCK FLAG AND DISABLE
EVL=6317/ENABLE SOLENOID AND SCALAR
DSLL=6319/DISABLE SOLENOID AND SCALAR

/STEPPING MOTOR VE+STEP IOT'S-

M1F=6321/MOTOR 1 FORWARD
M2F=6331/MOTOR 2 FORWARD
M3F=6334/MOTOR 3 FORWARD
M4F=6341/MOTOR 4 FORWARD
M1R=6322/MOTOR 1 REVERSE
M2R=6332/MOTOR 2 REVERSE
M3R=6333/MOTOR 3 REVERSE
M4R=6342/MOTOR 4 REVERSE

/FOCAL SUBROUTINE CALLS

FEVT=JMS I 7/FLT PT INTRPTR
POPATAD I 13/RESTORE AC
NEGATE=JMS I 51/NEGATE FLAG
INTEGR=JMS I 53/FIX FLAG
RETURN=JMP I 136/RETURN
PUSH=JMS I 148/RECURSIVE SUBR TN CALL
POP=JMP I 141/BRN RETURN
PUSH=JMS I 142/SAVE AC
Army Materials and Mechanics Research Center
Watertown, Massachusetts 02172

UNCLASSIFIED
UNLIMITED DISTRIBUTION
Key Words

Technical Report AMRL TR 76-38, November 1976, 25 pp
Tables, D/A Project 111611002AH42,
AMC Code 61102.11.H4200

SPASTIC 76 is an update of previously reported programs written for a minicomputer
to permit data acquisition with a small-angle X-ray diffractometer. SPASTIC
denotes System for Programming Angles, Scatter, and Timer by Internal Counting, and indicates
the general approach used for automation, involving a simple interface and stepping
motor control. The present programs are written for two diffractometers of the
Bonne-Hart and the Kratky designs, and run on a PDP-11 computer with 8,192 words of
core memory. The various programs include routines for finding the zero position
and integral breadth of the primary beam, and for step-scanning through the scattering
regions. The latter routine incorporates integrations for the Porod invariant.

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core memory. The various programs include routines for finding the zero position
and integral breadth of the primary beam, and for step-scanning through the scattering
regions. The latter routine incorporates integrations for the Porod invariant.
PUSH=JMS I 143/AUX FLT PT VAR
POPF=JMS I 144/RESTORE FLT PT VAR
PRINT=JMS I 151/PRINT CHAR
ERROR=JMS I 166/ERROR RECOVERY
FIXTAB
/ /MEMORY FIELD CONTROL IUTS
CDF=6201
ClF=6202
/ /FOCAL STORAGE LOCVS
/ /PT1=30
EX1=40
FLAC=44
ADD=61
CHAR=66
P7780=101
P7600=104
C260=113
MS=150
START=177
FYTABF=374
ILGL=634
JS1=1437
EVAL=1615
FYTA8L=2155
SVAL=2601
EXHUN=2725
RECOVER=2740
DIV=6757
PRMT=7577
DL13=7557
LIVER=100 /FIELD 1
DL16d=120 /FIELD 1
KL14=125 /FIELD 1
/ /S.F.A.S.T.I.C* - TAPE 2
/PAGE ZERO PATCH-FOCAL 69
/ /START OF INTERRUPT SVC MODIFIED
/ /NOT INTENDED FOR PDP-5 OR PDP-8S
/ /FIELD 0/SET FIELD ZERO INDICATOR
*1
0001 5402 Jmp 1 ++1
0002 6172 INTRPX /ADS MODFD
0003 0000 SAVAX,0
/ /CHANGE BUTTON
*35
0035 4673 BUIPE=2
/ /MODIFY INITIALIZN ADS
*176
0176 4365 BEGINX
/ /MODIFY FUNCTION ADDRESS TABLE
*FYTABF+3
0377 4757 FOPR

11
0400 5023 FSOL
0401 5289 FDHV
0402 4717 FSRT
0403 5185 #TL
0404 1142 FADV
/* PUT ERRORS IN NEXT TWO LOCUS SINCE SIN, COS ARE DROPPED */
0405 2725 ERRORS
0406 3725 ERRORS
/
/* AND FUNCTION - CALLED BY FADV(11,IP,...) */
/* THIS FUNCTION IS REENTRANT, ARGUMENT LIST UNLIMITED */
/* ARG6 ASSIGNED IN RANGE M=4845, NO CHECK NAD2 */
0442 4453 FADV+INTEG
0443 4548 PUSHA
0444 4540 PUSHQ
0445 1343 ARR
0446 5354 JMP *+6
0447 4453 INTEG
0448 7206 CLA
0451 1413 POPA
0452 3046 AND FLAC+1
0453 5343 JMP FADV+1
0454 1413 POPA / EXIT
0455 3846 DCA FLAC+2
0456 5536 RETURN
/
/* RETAIN LIBRARY COMMAND AT LOCN 1173 (2-74) */
/* ARGUMENT EVALUATOR */
01343 1066 ARGTAD CHAR
01344 1353 TAD MCOMMA
01345 7646 S A CLAYLAST CHAR=,*?
01346 5352 JMP *+4
01347 4508 PUSHJ /*YES-GET ANOTHER ARG */
01350 1612 EVAL-1
01351 7001 IAC /*AND SKIIP INSTR ON RETURN */
01352 5541 POPJ /*OTHERWISE NO SKIP */
01353 7524 MCOMMA,-254
/
01553 6321 IOTBL,M1F / LIST OF STEPPING MOTOR IOTES
01554 6322 M1
01555 6331 M2K
01556 6324 M2k
01557 6334 M3F
01558 6332 M3K
01559 6341 M4F
01561 6342 M4K
/
/* CHANGE FUNCTION NAMES - SEE FOCAL RUN FOR CODING */
/* CODE FOR FXYZ IS 4X+2Y+Z */
/* CODE FOR FYZ IS 2Y+Z */
/* CODE FOR FZ IS Z */
/* WHERE X,Y,Z ARE ASCII VALUES */
01563 6342 M4K

2170 2656 2656 /FOPH
2171 2666 2666 /FSOL
2172 2612 2612 /FDHV
2173 2652 2652 /FSET

12
2174 2657 /FTIM
2175 2544 2544 /FAND

/CHANGES IN INTERRUPT SERVICE PAGE

/2640 /BREAK@/OLD SAVAC - RESERVE FOR HARDWARE SCALAR

/#2663

2663 3801 INTNR/DCA SAVAC/REACHED VIA INTKP
2664 6311 SVC
2665 2654 JMP LCKSVC/SERVICE CLOCK
2666 6941 BACK(ISF)

/#2640

2640 5576 JMP I START=1/PROVIDED CNTL=C WITH NEW RECOVER

/#2653

2653 7410 SKP/DELETE PDP-8S PARITY CHECK
2654 8276 LCKSVC/CKSVC

/#2657

2657 1003 TAD SAVAC/RESTORE AC FROM NEW LOCV

/

/SP-A.S.-T.I.C. - TAPE 3

/CHANGE WRITE INSTRUCTION HEADING (4K)

/#3211

3211 2388 2388 /SP
3212 0123 0123 /AS
3213 2411 2411 /TI
3214 0354 0354 /C
3215 6766 6766 /76

/8IN PUNCH RTV - SAME AS DEC=MK=YYAA-PB

/WITH START ADS CHANGED TO 3465

/

/DROPPED IN THIS VERSION - CANT PUNCH FIELD 1

/

/SP-A.S.-T.I.C. - TAPE 4

/modify starting procedure to give initial IOUTS to

/SOLENOID AND CLOCK

/#4365

4365 6352 BEGINX,DISL /DISABLE SOLENOID AND SCALAR
4366 6316 DSCF /DISABLE CLOCK AND CLEAR FLAG
4367 7410 SKP
4370 4773 JUNCVR

/

/CERTAIN LAB-8 IOUTS IN INITIAL RTV INTERFERENCE
/IF STEPPING MOTOR IOUTS M2F AND M4R (6331,6342)

/IF YOU USE A LAB-8 SYSTEM THESE STEPPING MOTOR IOUTS
/MUST BE CHANGED IN THE HARDWARE

/ERASE OFFENDING LAB-8 IOUTS -

/#4400

4400 7000 /NOP
4436 7000 /NOP

#4436

/PDP-5 AND PDP-8S ARE FORBIDDEN

/PROBLEM IS SPACE LIMITATIONS

/IN PAGE 000 AND PAGE 2600

/

13
HALT ON INITIAL DIALOGUE, PDP-8S
NO ROOM ON PAGE 0000 FOR
MEMORY PARITY CHECK
PDP-8S IS PROBABLY TOO SLOW ANYWAY

*4456
4456 7402 HLT
/
HALT ON INITIAL DIALOGUE, PDP-8S
NO ROOM FOR USE OF LOCN
0002 AS JMP INSTRUCTION

*4463
4463 7402 HLT /
/ THESE COMPUTERS COULD BE USED
/ IF THE 8K OPTION IS DROPPED
/ BY MAKING USE OF LOCNS
/ 0167-0175 UV PAGE 0000 /
/
*4523
4523 7200 CLA / PATCH OUT INIT
/
/ SET BUFFER LIMIT ON INITIALIZ
*4557
4557 4673 BUFEDV-2
/
/
/ S.P.A.S.T.I.C. - TAPE 5
/ FSET ROUTINE - SETS TIME AND COUNT LIMITS
/ ARGUMENTS = (TL, SL, MI)
/ TL = PRESET TIME LIMIT, CLOCK UNITS
/ SL = PRESET COUNT LIMIT
/ MI = MOTOR PULSE INTERVAL, CLOCK UNITS
/ ZERO ARG'S ARE IGNORED
/ NEG ARG'S = EXHAU
/ CLOCK UNIT = 1 - 300TH SEC
/
*4675
4675 4540 ARGINT, PUSM / GET ANOTHER ARGUMENT
4676 1343 ARG
4677 5541 POPJ / NO ARG, RETURN WITHOUT SKIP
4700 4453 INTEXT, INTEG / ENTRY FOR FIRST ARG
4701 7450 SNA
4702 1045 TAD FLAC+1
4703 7650 SNA CLA
4704 5541 POPJ / ARG=0, RETURN WITHOUT SKIP
4705 1044 TAD FLAC
4706 1346 TAD M27
4707 7640 SNA CLA
4710 4566 ERROR / ARG EXCEEDS 2 TO 23RD (APPROX 4E6)
4711 1045 TAD FLAC+1
4712 7710 SNA CLA
4713 4566 ERROR / ARG=-, ERROR MSG
4714 4451 NEGATE / ARG +, MAKE IT -
4715 7001 IAC
4716 5541 POPJ / SKIP INSTR ON RETURN
/
4717 4540 FSET, PUSM / FSET STARTS HERE
4720 4700 INTEXT
4721 5307 JMP SLIN / TL=0, IGNORE IT
4722 4352 JMP RNCH

14
ENTRY TO {FOPH} FUNCTION

/FOPH(0) - READ SC, TM WITHOUT STOPPING THEM
/FOPH(1) - STOP SC, TM, THEN READ THEM
/FOPH(2) - RESET AND START SC, TM
/FOPH(3) - RETURN TIMER STATUS, FOR HIC RATE
/FOPH(4) - RETURN MOTOR STATUS = INTEGER 0 THRU 15
/FOPH(5) - STOP ALL MOTORS, RETURN FOPH=0

/USE FOPH(5) TO INITIALIZE SPASTIC PROGRAMS IN CASE
/SYSTEM HAD BEEN STOPPED WITH A MOTOR RUNNING
/OTHERWISE THAT MOTOR WILL RESTART WHENEVER CCF IS EXECUTED

4757 4453  FOPH=INTEGR
4760 7510  SPA
4761 4566  ERROR / NEGATIVE ARG
4762 1120  TAD M5
4763 7740  SMA SZA CLA
4764 5361  JMP +3 / ARG EXCEEDS 5
4765 1371  TAD BRANCH
4766 4542  PUSHA / SAVE ADS
4767 1046  TAD FLAC+2
4770 5541  POPJ / BRANCH OUT
4771 5112  BRANCH+XFOPH

4772 5033  SOLND
4773 7300  NURCVH CLA CLL / RESPONSE TO CTRL-C OR RESTART AT 200
4774 4772  JMS 1 --2
4775 6314  DSCK

15
4776 5777 JMP I *+1
4777 2740 /RECOVR / CHANGE TO 7600 TO JUMP TO DISC MONITUR
/NOTE THAT SUCH A CHANGE AFFECTS RESTART AT 8000 AS WELL
/AS CTRL-C KEYBOARD SIGNAL
/IN SUCH EVENT USE 2740 AS RESTART ADS AND
/REMEMBER THAT HARDWARE MAY NOT BE INITIALIZED
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5042 7001 IAC
5043 3704 DCA I LOCRUN / CLEAR HI CT HAIX FLAG
5044 3947 DCA SOLVAL / SAUK AC
5045 3622 DCA I LMBEAK
5046 5633 JMP I SOLVD
5047 0000 SOLVAL & / STORE FOR FSOL(2)

THE FLAG HTVS ARE ON THE SAME PAGE AS REST
AND ARE MOVED IF RESTMT IS MOVED

/SCALAR AND TIMER READ OPERATIONS
/SCALAR CONTENTS PLACED AT 5', TIMER AT T'

/FI-STOP THEM FIRST
/FI DOES NOT CLEAR VEG RUN FLAG

5050 2704 F1 ISZ I LOCRUN
/MERGE WITH F3, DYNAMIC READ
5051 3062 F0, TAD SCKODE
5052 3061 DCA ADD
5053 4540 PUSHJ
5054 1437 GSI
5055 6002 LGF/FREEZE COUNT+TIME
5056 4407 FEVT
5057 0610 FGET I LCOUNT
5058 2606 FSUB I LGOL
5059 7000 FNOH
5060 6430 FPUT I PT1
5061 0000 FEXT
5062 1303 TAD TMKODE
5063 3061 DCA ADD
5064 4540 PUSHJ
5065 1437 GSI
5066 4407 FEVT
5067 0614 FGET I LTIM
5068 2612 FSUB I LTIL
5069 7000 FNOH
5070 6430 FPUT I PT1
5071 0000 FEXT
5072 6001 ION

/MERGE WITH F3, TIMER STATUS CHECK

5073 1704 F3, TAD I LOCRUN/SET FUNCTION SGN = 0, OR+
5074 3545 DCA FCALC=1/TO COINCIDE WITH SIGN OF RUN
5075 5323 JMP DCFL2
5076 2347 SCKODE, 2347/PACKED
5077 2447 TMKODE, 2447/ASCII
5078 5370 LOCRUN/RUN

/FTIM-RUN SCALAR AND TIMER
/FOR PRESET COUNT OR TIME
/INTERVAL, THEN READ

/NOTE

/EITHER FOPH(2) OR FTIM(...-OPEN THE SOLENOID
/THIS MUST BE DONE SEPARATELY BY FSOL(1)
/ALSO, THESE ROUTINES MAY BE USED WITH SOLENOID
/CLOSED FOR TIME DELAY WITHOUT COUNTING

5105 4200 FTIM JMS RESTRT
5106 7100 CCL GML / DISPLAY LINK = 1 IN FTIM WAIT

17
5107  1704  TAD  I  LOCKUP
5110  7650  SCA  CLA
5111  5307  JMP  -2/  WAIT  FOR  PRESET
      /TABLE  FOR  POPO
      /DU  WOT  CHANGE  SEQUENCE  OF  LOCNS  XFOPR+1  TO  XFOPH+5
5112  5251  XFOPR,  JMP  F0
5113  5250  JMP  F1

/FR:  JRESET  AND  START  TIME-SCALAN>  RETURN  STATUS
5114  4900  JMS  RESTRT
5115  5877  JMP  F3
5116  5325  JMP  F4
      /F5  -  STOP  ALL  MOTORS
5117  3347  F5>DCA  STEP1
5120  3351  DCA  STEP2
5121  3353  DCA  STEP3
5122  3355  DCA  STEP4
5123  3546  DGCL2>DCA  FLAC+2
5124  5536  RETURV
      /CHECK  MOTOR  STATUS
      /POPO(4)  ROUTINE
5125  3046  F4>DCA  FLAC+2
5126  1355  TAD  STEP4
5127  4337  JMS  MCHK
5130  1353  TAD  STEP3
5131  4337  JMS  MCHK
5132  1351  TAD  STEP2
5133  4337  JMS  MCHK
5134  1347  TAD  STEP1
5135  4337  JMS  MCHK
5136  5536  RETURV
5137  0000  MCHK+9  /  CHECK  1  MOTOR,  SAVE  STATUS  AT  FLAC+2
5140  7108  CLL
5141  7640  SCA  CLA
5142  7620  CAL  /  SET  LINK=1  IF  RUNNING
5143  1946  TAD  FLAC+2
5144  7304  RAL
5145  3046  DCA  FLAC+2  /  SAVE  STATUS  AT  BIT  11
5146  5737  JMP  I  MCHK

/5147  0000  STEP1,0/MOTOR  1
5150  0000  0
5151  0000  STEP2,0/MOTOR  2
5152  0000  0
5153  0000  STEP3,0/MOTOR  3
5154  0000  0
5155  0000  STEP4,0/MOTOR  4
5156  0000  0
      /INCREMENT  A  DOUBLE  PRECISION  NUMBER
      /FOR  USE  ONLY  BY  CKSVC
5157  0000  DBLINC+8
5160  1757  TAD  I  DBLINC
5161  3374  DCA  TBD1
5162  7101  CLL  IAC
5163  1374  TAD  TBD1
5164  3375  DCA  TBD1+1
5165  2357  ISZ  DBLINC
5166  2775  ISZ  I  TBD1+1
5167  5757  JMP  I  DBLINC
5170  2774  ISZ  I  TBD1  /  INCRT  HI  BITS
5171  5757  JMP  I  DBLINC
5172  7020  CML  /  SET  LINK  IF  HI  BITS  OVERFLOW
S.T.I.C. - TAPE 7
/DEVC ROUTINE
/INITIATES STEPPING MOTOR DRIVES
/ARGUMENTS A1 THRU A4=
/NB OF STEPS FOR MOTORS 1-4
/ARGUMENTS ARE +6R- INTEGERS OR 0
/ZERO ARGUMENT LEAVES MOTOR UNAFFECTED
/FM MOTOR CAN BE STOPPED FOR CERTAIN ONLY BY KOPH(S)
/

S2000 6314 PDUV/DSCK / DISABLE CLOCK
S201 4543 PUSHF / INITIALIZE
S202 526L LSTEP1
S203 4544 POPF / 3 LOCW COUNTERS
S204 5254 LSTEP4
S205 1253 TAD MFOUR
S206 3261 DCA ARGLIM / LIMIT 4 ARGS
S207 4453 LOOP=INT3/FLT PT AC TO INTEGER
S208 7450 SWA
S209 1045 TAD FLAC+1
S210 7550 SVN CLA
S211 3253 JMP CADC
S212 1045 TAD FLAC+1
S213 7710 SPA CLA
S214 5230 JMP XADC
S215 4451 NEGATE/ARG++, MAKE IT -
S216 1666 TAD I GTIOT
S217 2266 ISZ GTIOT
S218 3232 JMP SETIOT
S219 2266 /ADC*ISZ GTIOT / FLT PT AC=0, IGNORE IT
S220 2266 ISZ GTIOT
S221 2265 ISZ PTIOT
S222 2264 ISZ LSTEP4
S223 3242 JMP ZJMP
S224 2266 /ADC*ISZ GTIOT / FLT PT AC=-
S225 1666 TAD I GTIOT
S226 3665 SETIOT=DCA 1 PTIOT/STOKE MOTOR IOT
S227 2266 ISZ GTIOT
S228 2265 ISZ PTIOT
S229 1045 TAD FLAC+1
S230 3664 DCA 1 LSTEP4
S231 2264 ISZ LSTEP4
S232 1046 TAD FLAC+2
S233 3664 DCA 1 LSTEP4/STOKE PULSE COUNT
S234 2264 ZJMP*ISZ LSTEP4 / DOUBLE PREC INTEGER
S235 3267 ISZ ARGLIM
S236 7410 SKP
S237 5252 JMP MDLY/4TH ARG DONE
S238 4540 PUSHF/NEXT ARG TO FLT PT AC
S239 1343 ARG
S240 7410 SKP / ARG LIST EXHAUSTED
S241 5207 JMP LOOP
S242 1371 MDLY=TAD MSPEED / SET DELAY 84
S243 3371 DCA MTXT / NEXT MOTOR STEP
S244 3754 DCA 1 LBK
S245 6312 CCF / ENABLE CLOCK
5256 6991 10N
5257 5556  RETURN
/
5260 5147 LSTEP1+STEP1
5261 5774 LCXTBL+CTABL
5262 1553 LMIOT+IOTBL
5263 7774 MFU+*4
5264 5147 LSTEP1+STEP1 / THREE
5265 5774 PTIOT+CTABL / VARIABLE
5266 1553 GTIOT+IOTBL / POINTERS
5267 0000 ANGLIM+0
/
/CLOCK INTERRUPT SERVICE
/INTERRUPT RATE 300 MRC
/GIVEN FIRST PRIORITY
5270 1754 CASVC+TAD I LBRT+GET SCALER DATA BREAK COUNT
5271 3357 DCA TCK
5272 3754 DCA I LBRT+ZERO THE SCALER
5273 1357 TAD TCK
5274 2121 AND FT2+0
5275 7640 SZA CLA/TEST FOR HIGH RATE
5276 5347 JMP HIKT
5277 6312 CFLG+CCF/ENABLE CLOCK AND SCALER
5280 1370 TAD RUN
5281 7640 SZA CLA/SOFTWARE SCALER-TIMER RUNNING?
5282 5317 JMP MINTCH+0
5283 7100 CUL
5284 1357 TAD TCK
5285 1362 TAD COUNT+2
5286 3362 DCA COUNT+2
5287 7430 SGL
5288 2361 ISZ COUNT+1
5289 7410 SKP
5290 2370 ISZ RUV/SCALE< LIMIT REACHED
5291 4756 JMS I LDBLI/INCRT TIME VALUE
5292 5365 TIME+1
5293 7430 SGL
5294 2370 ISZ RUV/TIMER LIMIT REACHED
5295 2371 MIRK+1/ISZ MTKT/MOTOR PULSE DUE?
5296 5755 JMP I LBACK+0
5297 1372 TAD MSPEED/YES
5298 3371 DCA MTKT
5299 1863 TAD MFUHR
5300 3357 DCA TCK
5301 1373 TAD LMKT
5302 3335 DCA LMNKT
5303 1374 TAD LM1IOT
5304 3375 DCA LMN1OT
5305 1735 MILOOP+TAD I LMNKT/MOTOR PULSE LOOP
5306 7658 SVA CLA
5307 5341 JMP NP0LS/NTH MOTOR IDLE
5308 4756 JMS I LDBLI/INCRT MOTOR STEP COUNT
5309 5147 LMN1OT+STEP1/VARIES
5310 1775 TAD I LM1IOT
5311 3340 DCA +*1
5312 7600 NOPL/MOTOR PULSE IOT
5313 2375 NP0LS+ISZ LM1IOT
5314 2335 ISZ LMNKT
5315 2335 ISZ LMN1KT
5316 2357 ISZ TCK/COUNT 4 MOTORS
5317 5331 JMP MILOOP
5318 5755 JMP I LBACK/ RETURN TO INTRPX

20
5347 6352 HIKT+DSSL/CLOSE SOLENOID
5350 3776 DCA I LSOLV
5351 1347 ADD HIKT/RATE EXCEEDS 3K KHZ
5352 3370 DCA HIN/SET FLAG NEGATIVE
5353 5277 JMP CLG/GO SVC MOTORS
5354 2600 LBRK,BREAK
5355 2606 LBACK,BACK
5356 5157 LDBL1,LDBLING
5357 0300 TCK,0
5360 2000 COUNT±2000 / SOFTWARE SCALER
5361 6000 6000 / SET COUNT HIG= VALUE AT LOAD TIME
5362 0000 0
5363 0000 0 / 4 WORD
5364 0027 TIME±27/SOFTWARE TIMER
5365 0000 0 / DO NOT CHANGE EXPNT
5366 0000 0
5367 0000 0 / READ BY 4 WORD
5367 0001 HUN,1/SOFTWARE SC-TM RUN INDICATOR
5371 7777 MTK±-1 /VARIABLES
5372 7777 MSPD±-1 / SET BY FSET-HI SPEED IN EFFECT AT LOAD
5373 5147 LMK±,STEP1
5374 5774 LMIOT,CXTBL
5375 5774 LMIOT,CATBL/VARIABLES
5376 5047 LSOLV,SOLVAL
5377

S-P-A-T-I-C - TAPE A
/TABLE OF MOTOR IOTS WITH PROPER DIRECTION CHOSEV *5774
5774 7000 CXTBL, NOP / MOTOR 1
5775 7000 NOP / MOTOR 2
5776 7000 NOP / MOTOR 3
5777 7000 NOP / MOTOR 4

/INTERRUPT RESPONSE - REACHED FROM LOCN 2
*6172
6172 3003 INTAPX, DCA SAVACX/NEW SAVE AC LOCN USED
6173 7010 RAR
6174 5775 JMP I +1
6175 2603 INTRPT

/COUNT AND TIME LIMITS
*6311
6311 0030 COUNT±30 / COUNT LIMIT SET AT 1000 AT LOAD TIME
6312 7777 7777
6313 7814 7814
6314 0000 0
6315 0027 TIMESEL±27 / TIME LIMIT SET AT 4096 SEC AT LOAD TIME
6316 7324 7324
6317 0000 0
6320 0000 0

*PRINT-1
7526 5757 JMP I DLIB /LIBRARY EXIT, 4K
*DLIB
7557 4773 NURCVR /4K POINTER (CLEARS HARDWARE)
THE FOLLOWING STUFF IS FOR 8K ONLY. TERMINATE
HERE WITH DOLLAR SIGN FOR 4K.

S.P.A.S.T.I.C. - TAPE 9
/PATCHES FOR 8K OVERLAY (OMIT FOR 4K)
FIELD 1
LIVE0+4

0104 4023 4023 / S
0105 2001 2001 /PA
0106 2324 2324 /ST
0107 1103 1103 /IC
0110 5467 5467 /7
0111 6649 6649 /6

0125 4773 \NEW EXIT FROM LIBRARY (CLEANS HARDWARE)
FIELD 6
DLIB

7557 0126 DLIB /RESTORE AS IN 8K OVERLAY (CHANGED EARLIER THIS PATCH)

ADD 2561
AND 1363
ANULIV 4675
ANULIX 2567
BACK 2696
BEGIN 4365
BHANCE 4771
BHREK 2699
BIFEND 4675
CFL3 5277
CHAIN 0066
CASCUC 5270
CATAL 5774
COUNT 5360
COUNTL 6311
COSIO 0113
DUBLING 5157
DQFLU 5123
DUFLU 6757
DLIB 7557
DLIBB 0190
ENHOLS 2725
EVAL 1613
FAL 0040
FAND 1142
FARK 5200
FLAC 0044
FNTABK 0374
FVTABL 2165
FVH 4757
FSET 4717
FSOL 5023
FTIM 5105
F0 5051
F1 5050
F3 5077
F4 5125
F5 5117
G51 1437

ADDIT 5966
ANDI 5347
ILGL 0634
INTHPT 2601
INTLPA 6172
INVIS 4760
IUZBL 1553
LHACK 5355
LHEAK 5023
LBRK 5354
LCASVC 2654
LCTI 5261
LCUL 589A
LCOUNT 5010
LBBLI 5356
LDIVL 4750
LIVED 0100
LMJITB 5262
LMJITD 5375
LMK 5335
LMSPD 4747
LMUT 5374
LMX 5373
LGRUY 5184
LQUP 5097
LRR 4751
LSOLV 5376
LSTEP 5264
LSTEP 5260
LTL 5912
LTIME 5014
LADC 5830
LMCH 5137
MCOMMA 1353
MDLY 5252
MFUOR 5663
MILN 4740
MSPEED 5372
MTAT 5371

NLOOP 5331
MRC44 5117
MRT7 4766
MS 2193
VOLSP 5341
VHCMV 4773
PKSHV 7597
PRUOR 5865
PRT 4930
P1680 0184
P7700 0181
RECOMV 2440
RESTART 5329
RLIB 0125
RMDR 4752
RHUN 5370
SAVACK 0003
SAU4 2601
SCODE 5108
SKT10 5232
SLIN 4727
SOLND 5073
SOLVAL 5047
START 0177
STEP 5147
STEP 5151
STEP 5153
STEP 5155
TCK 5357
TDB1 5174
TIME 5364
TIMEFL 6315
TAKODE 5103
TFOPK 5112
TADC 5293
THMSP 5240
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