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

C. RICHARD DESPER
POLYMER & CHEMISTRY DIVISION

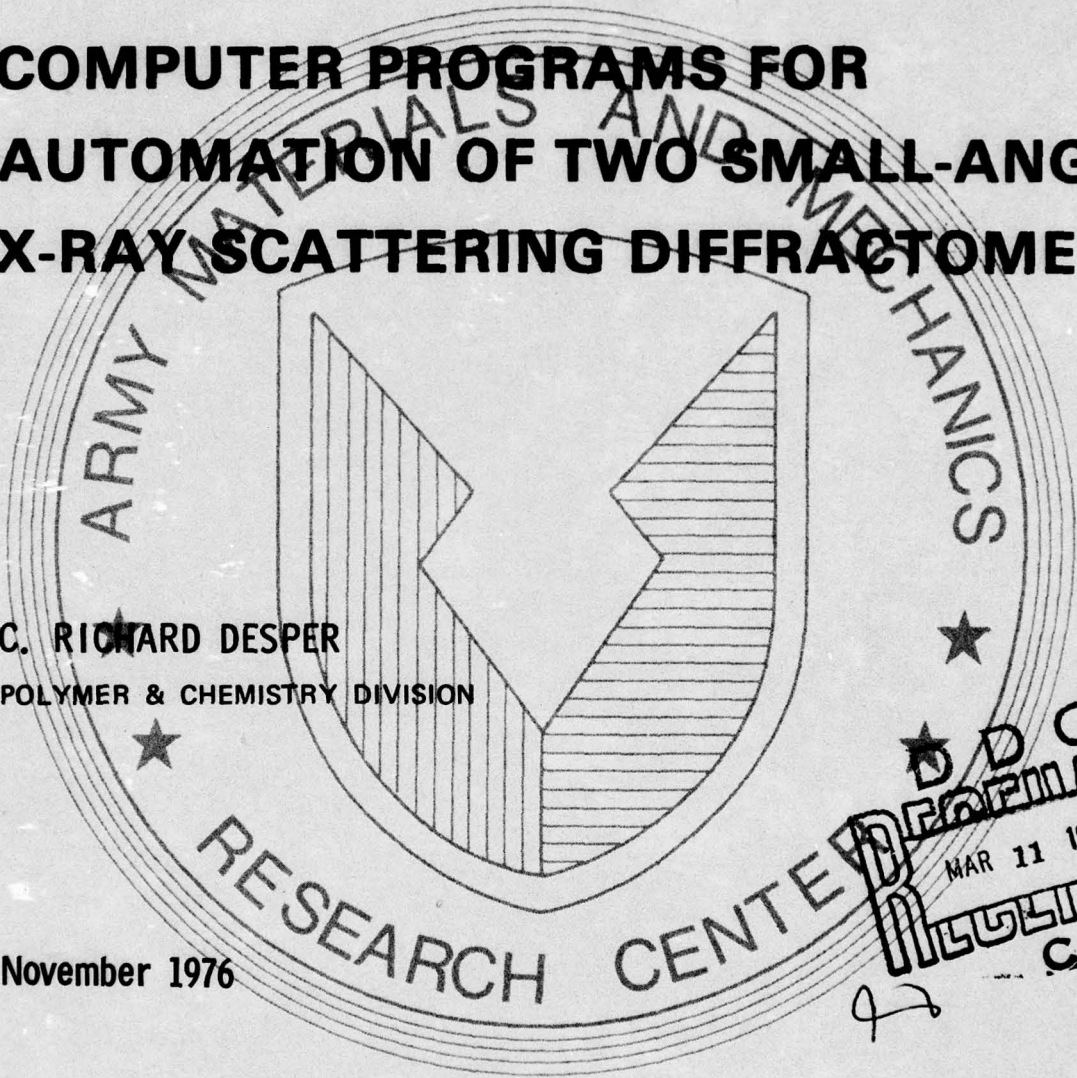
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ABSTRACT

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,¹ 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.

1. DESPER, C. R., and QUATIERI, T. F. *SPASTIC - A System for Programming Angles, Scaler, and Timer by Internal Counting*. Army Materials and Mechanics Research Center, AMMRC TR 72-17, June 1972.

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

SPASTIC 71	SPASTIC 76	Function
FADC	FDRV	Drive stepping motors
FDXS	FSET	Set timer limit, scaler limit, motor speed
FDIX	FOPR	Perform one of six possible operations
FEXP	FTIM	Run timer/scaler to limit value
FRAN	FSOL	Operate shutter solenoid
FAND	FAND	Logical AND

Table 2. SPASTIC 76 CONTROL FUNCTIONS

1.	FDRV (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 ²³ , or 8,288,608. 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 S' and T' without stopping them. ARG = 1 Stop scaler and timer, then read into S' 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 (0)	Reset, start, and run scaler/timer to count or time limit. Count and time are read into S' 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

Code	Meaning
08.47	Too many function arguments, or unmatched parentheses
19.72	Argument of FSET exceeds 2 ²³
19.75	Argument of FSET is negative
19.:9	Attempt to change count or time limit with timer running
19.;3	Argument of FOPR outside range 0 to 5
20.03	Timer restart with high count rate uncleared

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 2 θ . 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. AMR ZEROING PROGRAM

```

*#
C-8K SPASTIC.76

10.10 E
10.15 T "AMR ZEROING, TH IN SECONDS"!!S U=FOPR(5);S ML=10;S DL=5
10.20 A "AT 15",U,"USE 3"!!S AC=3;S A2=400*(3-U)/6;D 16;D 16.1
10.40 S U=FSOL(1);A "THRESHOLD",TH;S MT=6E5/TH
10.50 S U=FSET(MT,1E3,1);D 19;I (TH-SI)12.40;S U=FSET(3E6,3E6)

12.20 S TL=TL+1;I (400-TL)13.90;S A1=50;D 16;D 20;I (SI-TH)12.20
12.40 T "FOUND"!!S U=FSET(MT,1E4)

13.10 T " SECONDS CTS/SEC"!!S S1=0;S S2=0;S PS=PS+1
13.15 S TL=40*DL;S T0=-TL;S A1=T0;S HI=-1;D 16;F TC=T0,DL,TL;D 19
13.30 I (HI-20*SI)13.95;I (HI-20*S0)13.95;T "CG FOUND"!!S HT=S1/S2
13.35 S A1=HT-TL-DL;D 16;T "POSITION",%6.01,HT/ML," NOW=0"!!
13.50 S S2=(S2-(SI+S0)/2)*DL/ML;T "INTEGRAL BREADTH",S2/HI," SECONDS"!!
13.65 T "MAX"%6,HC," CTS",HI," CTS/SEC"
13.75 S TC=FSOL(0);D 16.1;T "QUIT"!!Q
13.90 T "NOT "D 12.40;G 13.75
13.95 T "HIGH TAIL"!!D 13.65;T "AT "D 13.35;I (PS-2)13.1
13.98 I (S-PS)13.75;S DL=2*DL;G 13.1

16.10 S U=FOPR(4);I (-U)16.1
16.20 I (-A1)16.3,16.3;S U=FDRV(A1-100)
16.25 S U=FOPR(4);I (-U)16.25;S A1=100
16.30 S U=FDRV(A1,A2);S A1=0;S A2=0

19.14 S U=FOPR(4);I (-U)19.14;S U=FTIM(0);I (U)19.9
19.16 S TI=T'/300;S SI=S'/TI;S S1=S1+TC*SI;S S2=S2+SI;I (-PS)19.14;R
19.18 T %6.01,TC/ML,SI;I (TC-T0) 19.2,19.19,19.2
19.19 S S0=SI
19.20 I (SI-HI)19.3,19.3;S HI=SI;S HT=TC;S HC=S'
19.30 S U=FDRV(DL);R
19.90 S U=FSOL(0);T "XS CT RATE"!!Q

20.05 S U=FOPR(2)
20.10 S U=FOPR(4);I (-U)20.1
20.20 S U=FOPR(1);I (U)19.9;D 19.16
*

```

Table 5. KRATKY ZEROING PROGRAM

```

*#
C-8K SPASTIC.76

10.10 E
10.15 T "KRATKY ZEROING, ANALYZER TO INTEGRAL"!!S U=FOPR(5);S ML=4
10.20 T "SLITS, MICRONS"!!A "1",DL,"2",U;S DL=(DL+U)/2.5
10.40 S U=FSOL(1);A "THRESHOLD",TH;S MT=6E5/TH
10.50 S U=FSET(MT,1E3,1);D 19;I (TH-SI)12.40;S U=FSET(3E6,3E6)

12.20 S TL=TL+1;I (100-TL)13.90;S A1=200;D 16;D 20;I (SI-TH)12.20
12.40 T "FOUND"!!S U=FSET(MT,1E4)

13.10 T " MICRONS CTS/SEC"!!S S1=0;S S2=0;S PS=PS+1
13.15 S TL=40*DL;S T0=-TL;S A1=T0;S HI=-1;D 16;F TC=T0,DL,TL;D 19
13.30 I (HI-20*SI)13.95;I (HI-20*S0)13.95;T "CG FOUND"!!S HT=S1/S2
13.35 S A1=HT-TL-DL;D 16;T "POSITION",%6.01,HT/ML," NOW=0"!!
13.50 S S2=(S2-(SI+S0)/2)*DL/ML;T "INTEGRAL BREADTH",S2/HI," MICRONS"!!
13.65 T "MAX"%6,HC," CTS",HI," CTS/SEC"
13.75 S TC=FSOL(0);D 16.1;T "QUIT"!!Q
13.90 T "NOT "D 12.40;G 13.75
13.95 T "HIGH TAIL"!!D 13.65;T "AT "D 13.35;I (PS-3)13.1,13.75

16.10 S U=FOPR(4);I (-U)16.1
16.20 I (-A1)16.3,16.3;S U=FDRV(0,0,A1-100)
16.25 S U=FOPR(4);I (-U)16.25;S A1=100
16.30 S U=FDRV(0,0,A1);S A1=0

19.14 S U=FOPR(4);I (-U)19.14;S U=FTIM(0);I (U)19.9
19.16 S TI=T'/300;S SI=S'/TI;S S1=S1+TC*SI;S S2=S2+SI;I (-PS)19.14;R
19.18 T %6.01,TC/ML,SI;I (TC-T0) 19.2,19.19,19.2
19.19 S S0=SI
19.20 I (SI-HI)19.3,19.3;S HI=SI;S HT=TC;S HC=S'
19.30 S U=FDRV(0,0,DL);R
19.90 S U=FSOL(0);T "XS CT RATE"!!Q

20.05 S U=FOPR(2)
20.10 S U=FOPR(4);I (-U)20.1
20.20 S U=FOPR(1);I (U)19.9;D 19.16
*

```


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

```

*GO
AMR ZEROING, TH IN SECOVDS
AT 15:3 USE 3
THRESHOLD:1000 FOUND

```

SECONDS	CTS/SEC	SECONDS	CTS/SEC	SECONDS	CTS/SEC
-- 20.0=	3.0	-- 6.0=	878.0	= 8.0=	335.0
-- 19.5=	6.0	-- 5.5=	1033.0	= 8.5=	273.0
-- 19.0=	6.0	-- 5.0=	1193.0	= 9.0=	190.0
-- 18.5=	6.0	-- 4.5=	1304.0	= 9.5=	126.0
-- 18.0=	8.0	-- 4.0=	1495.0	= 10.0=	88.0
-- 17.5=	4.0	-- 3.5=	1732.0	= 10.5=	58.0
-- 17.0=	9.0	-- 3.0=	1954.0	= 11.0=	27.0
-- 16.5=	7.0	-- 2.5=	2011.0	= 11.5=	16.0
-- 16.0=	13.0	-- 2.0=	2146.0	= 12.0=	12.0
-- 15.5=	12.0	-- 1.5=	2259.0	= 12.5=	8.0
-- 15.0=	12.0	-- 1.0=	2364.0	= 13.0=	3.0
-- 14.5=	12.0	-- 0.5=	2311.0	= 13.5=	5.0
-- 14.0=	18.0	= 0.0=	2290.0	= 14.0=	2.0
-- 13.5=	21.0	= 0.5=	2167.0	= 14.5=	3.0
-- 13.0=	22.0	= 1.0=	2111.0	= 15.0=	3.0
-- 12.5=	29.0	= 1.5=	2018.0	= 15.5=	2.0
-- 12.0=	35.0	= 2.0=	1869.0	= 16.0=	3.0
-- 11.5=	55.0	= 2.5=	1689.0	= 16.5=	1.0
-- 11.0=	82.0	= 3.0=	1546.0	= 17.0=	2.0
-- 10.5=	119.0	= 3.5=	1386.0	= 17.5=	2.0
-- 10.0=	132.0	= 4.0=	1277.0	= 18.0=	3.0
-- 9.5=	192.0	= 4.5=	1142.0	= 18.5=	0.0
-- 9.0=	258.0	= 5.0=	953.0	= 19.0=	0.0
-- 8.5=	309.0	= 5.5=	847.0	= 19.5=	2.0
-- 8.0=	344.0	= 6.0=	742.0	= 20.0=	1.0
-- 7.5=	474.0	= 6.5=	595.0	CG FOUND	
-- 7.0=	616.0	= 7.0=	527.0	POSITION=- 0.4 NOW=0	
-- 6.5=	774.0	= 7.5=	407.0	INTEGRAL BREADTH= 9.9 SECOVDS	
				MAX= 4728 CTS= 2364 CTS/SEC	

QUIT
*

Table 7. EXECUTION OF KRATKY ZEROING PROGRAM

```

*GO
KRATKY ZEROING, ANALYZER TO INTEGRAL

```

SLITS, MICRONS
1:150 2:140
THRESHOLD:1000 FOUND

MICRONS	CTS/SEC	MICRONS	CTS/SEC	MICRONS	CTS/SEC
-- 580.0=	7.0	-- 159.5=	964.0	= 261.0=	275.0
-- 565.5=	10.0	-- 145.0=	1063.0	= 275.5=	234.0
-- 551.0=	6.0	-- 130.5=	1227.0	= 290.0=	175.0
-- 536.5=	7.0	-- 116.0=	1304.0	= 304.5=	198.0
-- 522.0=	8.0	-- 101.5=	1332.0	= 319.0=	182.0
-- 507.5=	6.0	-- 87.0=	1426.0	= 333.5=	135.0
-- 493.0=	9.0	-- 72.5=	1467.0	= 348.0=	103.0
-- 478.5=	14.0	-- 58.0=	1540.0	= 362.5=	86.0
-- 464.0=	8.0	-- 43.5=	1520.0	= 377.0=	64.0
-- 449.5=	16.0	-- 29.0=	1520.0	= 391.5=	54.0
-- 435.0=	16.0	-- 14.5=	1581.0	= 406.0=	29.0
-- 420.5=	26.0	= 0.0=	1562.0	= 420.5=	17.0
-- 406.0=	27.0	= 14.5=	1555.0	= 435.0=	18.0
-- 391.5=	50.0	= 29.0=	1463.0	= 449.5=	5.0
-- 377.0=	45.0	= 43.5=	1432.0	= 464.0=	6.0
-- 362.5=	59.0	= 58.0=	1308.0	= 478.5=	3.0
-- 348.0=	62.0	= 72.5=	1202.0	= 493.0=	6.0
-- 333.5=	83.0	= 87.0=	1135.0	= 507.5=	4.0
-- 319.0=	104.0	= 101.5=	1009.0	= 522.0=	5.0
-- 304.5=	141.0	= 116.0=	943.0	= 536.5=	2.0
-- 290.0=	163.0	= 130.5=	754.0	= 551.0=	4.0
-- 275.5=	221.0	= 145.0=	668.0	= 565.5=	3.0
-- 261.0=	306.0	= 159.5=	542.0	= 580.0=	6.0
-- 246.5=	373.0	= 174.0=	473.0	CG FOUND	
-- 232.0=	438.0	= 188.5=	431.0	POSITION=- 14.6 NOW=0	
-- 217.5=	525.0	= 203.0=	397.0	INTEGRAL BREADTH= 343.8 MICRONS	
-- 203.0=	649.0	= 217.5=	374.0	MAX= 3164 CTS= 1582 CTS/SEC	
-- 188.5=	772.0	= 232.0=	306.0		
-- 174.0=	888.0	= 246.5=	267.0	QUIT	

QUIT
*

(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 \bar{Q}_m as a by-product of the step-scan program. The expression used² to calculate \bar{Q}_m is that suitable for use with experimental (smeared) intensity $\bar{Y}(m)$ obtained with long slits:

$$\bar{Q}_m = \int_0^{\infty} m \bar{Y}(m) dm \quad (1)$$

where m is the elevation variable in microns as defined in the Kratky instrument. The value of \bar{Q}_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 \bar{Q}_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 2θ 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 2θ ; TH, 2θ ; and TM LMT, time limit. In each case data is taken closely spaced at the lower 2θ values and more widely spaced at the higher values. The diffraction maximum occurs in both sets of data at $2\theta = 0.6^\circ$ (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

2. ALEXANDER, L. E. *X-Ray Diffraction Methods in Polymer Science*. Wiley-Interscience, New York, 1969, p. 292.

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

```

*W
C-8K SPASTIC,76

02.04 S U=FSOL(0);T !,"/SS, TH IN SECONDS",!;S ML=10
02.06 A "TH IS",TC,"AT IS",AC;!
02.10 A "CT LMT",MC,"TM LMT",MS;!
02.11 S MT=MS*300
02.20 S U=FSET(MT,MC,1);S I=0
02.30 TYPE "DATA PTS"
02.54 S I=I+1
02.56 A !"TH",TH(I),"AT",AT(I),"DL",DL(I)
02.60 I (DL(I)) 2.54,3.09,2.54

03.09 S AT(I)=3;S A1=(TH(I)-TC)*ML;S I=0;S QM=0;S TL=TH(I);S AL=AT(I)
03.18 D 2.54;S TC=TH(I);I (DL(I))3.25,3.50
03.25 D 6;D 5;S TC=TC+DL(I);S U=FSGN(DL(I))
03.27 S U=U*(TH(I+1)-TC-U*1E-4);I (-U)3.45
03.40 S A1=(TH(I+1)-TC+DL(I))*ML;S TC=TH(I+1);D 6;D 5;G 3.18
03.45 S A1=DL(I)*ML;G 3.25
03.50 S A1=-TC*ML;S TC=FSOL(0);D 6;D 5.1;T " END",!!!;Q

05.01 S U=FOPR(4);I (-U)5.01;S U=FSOL(2);I (-U)5.08
05.04 S U=FOPR(3);I (U)5.50;S U=FSET(600)+FOPR(2)+FSOL(1)
05.06 S U=FOPR(3);I (U)5.50,5.06
05.08 S U=FSET(MT);S U=FTIM(0);I (U)5.50;I (FABS(AC-AL))5.2,5.2
05.10 T !"QM",Q,," SEC SQD C/S, FOR AT",AL,;!;S QM=0;S TL=TC
05.20 T !6.01,0,1,"TH",TC,1," AT",AC,16," CTS",S'
05.30 S TI=T'/300;S SI=S'/TI;S QM=QM+(SI*TC+SL*TL)*(TC-TL)/2
05.40 T !6.04," IV",SI;S TL=TC;S SL=SI;S AL=AC;R
05.50 T !,"XS CT RATE",!;S U=FSOL(0);Q

06.05 S A2=800*(AT(I)-AC)/6;S AC=AT(I)
06.10 S U=FOPR(4);I (-U)6.10
06.15 I (-A1)6.30,6.30
06.20 S U=FDRV(A1-100,A2);S A2=0;S A1=100;G 6.10
06.30 S U=FDRV(A1,A2);S A1=0;S A2=0

```

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

```

*W
C-8K SPASTIC,76

02.04 S U=FSOL(0);T !,"/SS, TH IN MINUTES",!;S ML=600
02.06 A "TH IS",TC,"AT IS",AC;!
02.10 A "CT LMT",MC,"TM LMT",MS;!
02.11 S MT=MS*300
02.20 S U=FSET(MT,MC,1);S I=0
02.30 TYPE "DATA PTS"
02.54 S I=I+1
02.56 A !"TH",TH(I),"AT",AT(I),"DL",DL(I)
02.60 I (DL(I)) 2.54,3.09,2.54

03.09 S AT(I)=3;S A1=(TH(I)-TC)*ML;S I=0;S QM=0;S TL=TH(I);S AL=AT(I)
03.18 D 2.54;S TC=TH(I);I (DL(I))3.25,3.50
03.25 D 6;D 5;S TC=TC+DL(I);S U=FSGN(DL(I))
03.27 S U=U*(TH(I+1)-TC-U*1E-4);I (-U)3.45
03.40 S A1=(TH(I+1)-TC+DL(I))*ML;S TC=TH(I+1);D 6;D 5;G 3.18
03.45 S A1=DL(I)*ML;G 3.25
03.50 S A1=-TC*ML;S TC=FSOL(0);D 6;D 5.1;T " END",!!!;Q

05.01 S U=FOPR(4);I (-U)5.01;S U=FSOL(2);I (-U)5.08
05.04 S U=FOPR(3);I (U)5.50;S U=FSET(600)+FOPR(2)+FSOL(1)
05.06 S U=FOPR(3);I (U)5.50,5.06
05.08 S U=FSET(MT);S U=FTIM(0);I (U)5.50;I (FABS(AC-AL))5.2,5.2
05.10 T !"QM",Q,," MIN SQD C/S, FOR AT",AL,;!;S QM=0;S TL=TC
05.20 T !6.03,0,1,"TH",TC,1," AT",AC,16," CTS",S'
05.30 S TI=T'/300;S SI=S'/TI;S QM=QM+(SI*TC+SL*TL)*(TC-TL)/2
05.40 T !6.04," IV",SI;S TL=TC;S SL=SI;S AL=AC;R
05.50 T !,"XS CT RATE",!;S U=FSOL(0);Q

06.05 S A2=800*(AT(I)-AC)/6;S AC=AT(I)
06.10 S U=FOPR(4);I (-U)6.10
06.15 I (-A1)6.30,6.30
06.20 S U=FDRV(A1-100,A2);S A2=0;S A1=100;G 6.10
06.30 S U=FDRV(A1,A2);S A1=0;S A2=0

```


Table 10. KRATKY STEP-SCAN PROGRAM, ANGLE IN MICRONS

```

*V
C-8K SPASTIC,76

02.04 S U=FSOL(0);I !,"/SS, TH IN MICRONS",!;S ML=8
02.06 A "PRESENT TH",TC;!
02.20 S U=FSET(0,0,1)+FOPR(1);S I=0;I "DATA PTS"
02.54 S I=I+1
02.56 A !"TH",TH(I),"DL",DL(I)
02.60 I (DL(I)) 2.54,3.09,2.54

03.09 S A1=(TH(1)-TC) 2 I=0;S QM=0;S TL=TH(1);D 6
03.10 I (-FOPR(4))
03.11 T !,"SET ANALYZER TO DIFFERENTIAL"!
03.12 T "USE NICKEL FILTER",!!!;S U=FSOL(1)
03.13 A "CT LMT",MC,"TM LMT",MS,!;S MT=MS*300
03.14 I (FOPR(3))5.50;S U=FSET(MT,MC)
03.18 D 2.54;S TC=TH(1);C...NO ATTENUATOR WHEEL
03.20 D 6;D 5;I (DL(1))3.25,3.50
03.25 S TC=TC+DL(1);S U=FSGN(DL(1))
03.27 S U=U*(TH(I+1)-TC-U*IE-4);I (-U)3.45
03.40 S A1=(TH(I+1)-TC+DL(1))*ML;G 3.18
03.45 S A1=DL(1)*ML;G 3.20
03.50 S A1=-TC*ML;S TC=FSOL(0);D 6;T " QM",QM," M SQD C/S"!!!;Q

05.01 S U=FOPR(4);I (-U)5.01;S U=FSOL(2);I (-U)5.08
05.04 S U=FOPR(3);I (U)5.50;S U=FSET(1500)+FSOL(1)+FOPR(2)
05.06 S U=FOPR(3);I (U)5.50,5.06
05.08 S U=FSET(MT);S U=FTIM(0);I (U)5.50
05.20 T #6,#!,"TH",TC," CTS",S'
05.30 S TI=T'/300;S SI=S'/TI;S QM=QM+(SI*TC+SL*TL)*(TC-TL)/2
05.40 T #6,#!," IN",SI;S TL=TC;S SL=SI;R
05.50 T !,"XS CT RATE",!;S U=FSOL(0);Q

06.10 S U=FOPR(4);I (-U)6.10
06.15 I (-A1)6.30,6.30
06.20 S U=FSOL(0)+FDRV(0,0,A1-200)
06.25 S U=FOPR(4);I (-U)6.25;S A1=200
06.30 S U=FDRV(0,0,A1);S A1=0
*

```

Table 11. KRATKY MULTIPLE STEP-SCAN PROGRAM, ANGLE IN MICRONS

```

*V
C-8K SPASTIC,76

02.04 S QI=FSOL(0);I !,"/MS, TH IN MICRONS",!;S ML=8
02.06 A "PRESENT TH",TC;!
02.10 A "NR OF MULTIPLE SCANS",CY,!;S KC=0
02.20 S U=FSET(0,0,1)+FOPR(1);S I=0
02.54 S I=I+1;I #2,#!,"GRP",I
02.56 A !"TH",TH(I),"DL",DL(I)
02.60 I (DL(I)) 2.54,3.06,2.54

03.05 T " QM",QM," M SQD C/S"!!;S QI=QI+QM
03.06 S KC=KC+1;IF (CY-KC)3.50
03.09 S A1=(TH(1)-TC)*ML;S I=0;S QM=0;S TC=TH(1);S TL=TC;D 6
03.10 I (-FOPR(4))3.10;I (1-KC)3.18
03.11 T !,"SET ANALYZER TO DIFFERENTIAL",!,"USE NICKEL FILTER",!!!
03.12 A "CT LMT",MC,"TM LMT",MS,!;S MT=MS*300
03.14 S U=FSOL(1);I "SAMPLE I.D.";I (FOPR(3))5.50;A U
03.18 S I=I+1;S TC=TH(1)
03.20 D 6;D 5;I (DL(1))3.25,3.05
03.25 S TC=TC+DL(1);S U=FSGN(DL(1))
03.27 S U=U*(TH(I+1)-TC-U*IE-4);I (-U)3.45
03.40 S A1=(TH(I+1)-TC+DL(1))*ML;G 3.18
03.45 S A1=DL(1)*ML;G 3.20
03.50 S A1=-TC*ML;S TC=FSOL(0);D 6;T !"AVERAGE "!!;S QM=QI/CY;D 3.05;Q

05.01 S U=FOPR(4);I (-U)5.01;S U=FSOL(2);I (-U)5.08
05.04 S U=FOPR(3);I (U)5.50;S U=FSET(1500)+FSOL(1)+FOPR(2)
05.06 S U=FOPR(3);I (U)5.50,5.06
05.08 S U=FSET(MT,MC);S U=FTIM(0);I (U)5.50
05.30 S TI=T'/300;S SI=S'/TI;S QM=QM+(QI*TC+SL*TL)*(TC-TL)/2
05.40 T #6,#!,TC,S',#6,03,SI;S TL=TC;S SL=SI;R
05.50 T !,"XS CT RATE",!;S U=FSOL(0);Q

06.10 S U=FOPR(4);I (-U)6.10
06.15 I (-A1)6.30,6.30
06.20 S U=FSOL(0)+FDRV(0,0,A1-200)
06.25 S U=FOPR(4);I (-U)6.25;S A1=200
06.30 S U=FDRV(0,0,A1);S A1=0
*

```

Table 12. EXECUTION OF AMR STEP-SCAN PROGRAM

```

*GO

/SS, TH IN MINUTES
TH IS:0 AT IS:3
CT LMT:1E3 TM LMT:1200
DATA PTS
TH:5 AT:0 DL:1
TH:15 AT:0 DL:3
TH:60 AT:0 DL:0
TH= 5.000 AT= 0 CTS= 1000 IN= 3.4468
TH= 6.000 AT= 0 CTS= 1000 IN= 2.4962
TH= 7.000 AT= 0 CTS= 1000 IN= 1.8854
TH= 8.000 AT= 0 CTS= 1000 IN= 1.5868
TH= 9.000 AT= 0 CTS= 1000 IN= 1.3465
TH= 10.000 AT= 0 CTS= 1000 IN= 1.1234
TH= 11.000 AT= 0 CTS= 1000 IN= 1.0215
TH= 12.000 AT= 0 CTS= 1000 IN= 0.9734
TH= 13.000 AT= 0 CTS= 984 IN= 0.8200
TH= 14.000 AT= 0 CTS= 940 IN= 0.7833
TH= 15.000 AT= 0 CTS= 892 IN= 0.7433
TH= 15.000 AT= 0 CTS= 904 IN= 0.7533
TH= 18.000 AT= 0 CTS= 814 IN= 0.6783
TH= 21.000 AT= 0 CTS= 868 IN= 0.7233
TH= 24.000 AT= 0 CTS= 802 IN= 0.6683
TH= 27.000 AT= 0 CTS= 890 IN= 0.7417
TH= 30.000 AT= 0 CTS= 1000 IN= 0.8910
TH= 33.000 AT= 0 CTS= 1000 IN= 1.0449
TH= 36.000 AT= 0 CTS= 1000 IN= 1.4039
TH= 39.000 AT= 0 CTS= 1000 IN= 1.2669
TH= 42.000 AT= 0 CTS= 1000 IN= 0.9537
TH= 45.000 AT= 0 CTS= 712 IN= 0.5933
TH= 48.000 AT= 0 CTS= 528 IN= 0.4400
TH= 51.000 AT= 0 CTS= 426 IN= 0.3550
TH= 54.000 AT= 0 CTS= 338 IN= 0.2817
TH= 57.000 AT= 0 CTS= 322 IN= 0.2683
TH= 60.000 AT= 0 CTS= 288 IN= 0.2400
QM= 0.124484E+04 MIN SOD C/S, FOR AT= 0
END

```

Table 13. EXECUTION OF KRATKY STEP-SCAN PROGRAM

```

*GO

/SS, TH IN MICRONS
PRESENT TH:0
DATA PTS
TH:500 DL:100
TH:1000 DL:200
TH:4000 DL:0
SET ANALYZER TO DIFFERENTIAL
USE NICKEL FILTER

CT LMT:1E3 TM LMT:100
TH= 500 CTS= 1000 IN= 103.59
TH= 600 CTS= 1000 IN= 63.87
TH= 700 CTS= 1000 IN= 54.43
TH= 800 CTS= 1000 IN= 53.19
TH= 900 CTS= 1000 IN= 49.59
TH= 1000 CTS= 1000 IN= 43.59
TH= 1200 CTS= 1000 IN= 37.30
TH= 1400 CTS= 1000 IN= 34.86
TH= 1600 CTS= 1000 IN= 31.43
TH= 1800 CTS= 1000 IN= 32.25
TH= 2000 CTS= 1000 IN= 36.68
TH= 2200 CTS= 1000 IN= 41.64
TH= 2400 CTS= 1000 IN= 47.02
TH= 2600 CTS= 1000 IN= 43.65
TH= 2800 CTS= 1000 IN= 33.76
TH= 3000 CTS= 1000 IN= 24.35
TH= 3200 CTS= 1000 IN= 20.89
TH= 3400 CTS= 1000 IN= 17.93
TH= 3600 CTS= 1000 IN= 16.50
TH= 3800 CTS= 1000 IN= 16.07
TH= 4000 CTS= 1000 IN= 14.84
QM= 0.233214E+09 M SQD C/S
*

```

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 \hat{Q}_m . Although a small drift may be indicated by the systematic changes in \hat{Q}_m over the ten scans, the effect appears only in the third digit and leads to less than 1% error in \hat{Q}_m .

A greater source of error lies in the fact that the integral for the Porod invariant (Eq. 1) has been truncated to cover something less than the full range zero to infinity.

Table 14. RESULTS OF KRATKY MULTIPLE STEP-SCAN EXECUTION

Scan No.	Porod Invariant
1	0.111372 E + 09
2	0.112771 E + 09
3	0.112852 E + 09
4	0.113289 E + 09
5	0.113972 E + 09
6	0.114016 E + 09
7	0.115220 E + 09
8	0.114224 E + 09
9	0.113563 E + 09
10	0.113561 E + 09
Average	0.113584 E + 09 ± 0.90%

APPENDIX. PALD ASSEMBLY OF SPASTIC 76

```

/      S.P.A.S.T.I.C. - TAPE 1 - 19 FEB 1976
/FSIN AND FCOS DROPPED, LIBRARY COMMAND ALLOWED
/
/SYSTEM FOR PROGRAMMING ANGLES, SCALAR, AND TIMER
/BY INTERNAL COUNTING
/OVERLAY FOR FOCAL, 1969 FOR XRAY SCATTERING EXPERIMENTS
/RICHARD DESPER, AMMHC, WATERTOWN, MASS.
/COMPATIBLE WITH FOCAL 69
/      ...DO NOT USE INIT...
/4 WORD OVERLAY CAN BE USED, LOAD B4 SPASTIC
/8K OVERLAY SHOULD BE USEABLE, LOAD B4 SPASTIC
/
/FOCAL FLOATING POINT OPERATORS
/
/      ...CAUTION...
/SOME OF THESE DIFFER FROM STANDARD
/FLOATING POINT OPERATORS
/
/      .....NOTE..... PALD DOES NOT RECOGNIZE FIXMRI
/      USE PAL III INSTEAD OR DELETE FIXMRI, SINCE
/      FLXTAB WILL TAKE CARE OF IT IN PALD
/
FGET=0000
FADD=1000
FSUB=2000
FDIV=3000
FMUL=4000
FPOW=5000
FPUT=6000
/THE ABOVE 7 SYMBOLS REQUIRE FIXMRI FOR PAL III
FNOR=7000
FEXT=0000
/
/HARDWARE IOT'S
/
SNCF=6311/SKIP IF NO CLOCK FLAG
CCF=6312/CLEAR CLOCK FLAG, ENABLE CLOCK
DSCK=6314/DISABLE CLOCK
DSCF=6316/CLEAR CLOCK FLAG AND DISABLE
ENSL=6351/ENABLE SOLENOID AND SCALAR
DSSL=6352/DISABLE SOLENOID AND SCALAR
/STEPPING MOTOR VE-STEP IOTS-
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=6324/MOTOR 2 REVERSE
M3R=6332/MOTOR 3 REVERSE
M4R=6342/MOTOR 4 REVERSE
/
/FOCAL SUBROUTINE CALLS
/
FENT=JMS I 7/FLT PT INTRPTR
POPA=TAD I 13/RESTORE AC
NEGATE=JMS I 51/NEGATE FLAC
INTEGR=JMS I 53/FIX FLAC
RETURN=JMP I 136/FUNCTION RETURN
PUSHJ=JMS I 140/RECURSIVE SUBRTN CALL
POPJ=JMP I 141/SUBRTN RETURN
PUSHA=JMS I 142/SAVE AC

```


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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 the 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.

Army Materials and Mechanics Research Center
Watertown, Massachusetts 02172
COMPUTER PROGRAMS FOR AUTOMATION OF TWO
SMALL-ANGLE X-RAY SCATTERING DIFFRACTOMETERS -
C. Richard Desper

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Key Words

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tables, D/A Project 1T161102AH42,
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PUSHF=JMS I 143/AVE FLT PT NBR
POPF=JMS I 144/RESTORE FLT PT NBR
PRIVTC=JMS I 151/PRINT CHAR
ERROR=JMS I 166/ERROR RECOVERY
FIXTAB

/

/MEMORY FIELD CONTROL IOTS
CDF=6201
CIF=6202

/

/FOCAL STORAGE LOCNS

/

PT1=30
EX1=40
FLAC=44
ADD=61
CHAR=66
P7700=101
P7600=104
C260=113
MS=120
START=177
FVTABF=374
ILGL=634
GSI=1437
EVAL=1613
FVTABL=2165
SAVLK=2601
ERRR5=2725
RECOVR=2740
DIV2=6757
PRNTH=7527
DLIB=7557
LINE0=100 /FIELD 1
DLIB8=120 /FIELD 1
RLIB= 125 /FIELD 1

/

/

/ S.P.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 I .+1
0002	6172	INTRPX /ADS MODFD
0003	0000	SAVACX,0

/

/CHANGE BOTTOM

0035	4673	BUFEND-2
------	------	----------

/

/MODIFY INITIALIZN ADS

0176	4365	BEGINX
------	------	--------

/

/MODIFY FUNCTION ADDRESS TABLE

0377	4757	FOPR
------	------	------

*FVTABF+3


```

0400 5023 FSOL
0401 5200 FDRV
0402 4717 FSET
0403 5105 F11M
0404 1142 FAND
      /PUT ERRORS IN NEXT TWO LOCNS SINCE SIN, COS ARE DROPPED
0405 2725 ERRORS
0406 2725 ERRORS
      /
      /AND FUNCTION - CALLED BY FAND(I1,I2...)
      /THIS FUNCTION IS REEVRANT, ARGUMENT LIST UNLIMITED
      /ARGS ASSUMED IN RANGE 0-4095, NO CHECK MADE
      *1142
1142 4453 FAND,INTEGR
1143 4542 PUSHA
1144 4540 PUSHJ
1145 1343 ARG
1146 5354 JMP .+6
1147 4453 INTEGR
1150 7200 CLA
1151 1413 POPA
1152 0046 AND FLAC+2
1153 5343 JMP FAND+1
1154 1413 POPA / EXIT
1155 3046 DCA FLAC+2
1156 5536 RETURN
      /
      /RETAIN LIBRARY COMMAND AT LOCN 1173 (2-74)
      /
      /ARGUMENT EVALUATOR
      /
      *1343
1343 1066 ARG,TAD CHAR
1344 1353 TAD MCOMMA
1345 7640 SZA CLA/LAS1 CHAR=,?
1346 5352 JMP .+4
1347 4540 PUSHJ /YES-GET ANOTHER ARG
1350 1612 EVAL-1
1351 7001 IAC /AND SKIP INSTR ON RETURN
1352 5541 POPJ /OTHERWISE NO SKIP
1353 7524 MCOMMA,-254
      /
      *1553
1553 6321 IOTBL,MIF / LIST OF STEPPING MOTOR IOTS
1554 6322 M1R
1555 6331 M2F
1556 6324 M2R
1557 6334 M3F
1560 6332 M3R
1561 6341 M4F
1562 6342 M4R
      /
      /CHANGE FUNCTION NAMES - SEE FOCAL EFUN 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
      *FNTABL+3
2170 2656 2656 /FOPR
2171 2666 2666 /FSOL
2172 2612 2612 /FDRV
2173 2652 2652 /FSET

```

```

2174 2657 2657 /FTIM
2175 2544 2544 /FAND
/
/CHANGES IN INTERRUPT SERVICE PAGE
*2600
2600 0000 BREAK,0/OLD SAVAC - RESERVE FOR HARDWARE SCALAR
/
*2603
2603 3201 INTRPT,DCA SAVLK/REACHED VIA INTRPX
2604 6311 SNCF
2605 5654 JMP I LCKSVC/SERVICE CLOCK
2606 6041 BACK,ISF
/
*2640
2640 5576 JMP I START-1/PROVIDED CNTRL-C WITH NEW RECOVER
*2653
2653 7410 SKP/DELETE PDP-9S PARITY CHECK
2654 5270 LCKSVC,CKSVC
/
*2657
2657 1003 TAD SAVACX/RESTORE AC FROM NEW LOCN
/
/
/
/ S.P.A.S.T.I.C. - TAPE 3
/CHANGE WRITE INSTRUCTION HEADING (4K)
*3211
3211 2320 2320 /SP
3212 0123 0123 /AS
3213 2411 2411 /TI
3214 0354 0354 /C,
3215 6766 6766 /76
/BIN PUNCH RTN - SAME AS DEC-08-YXYA-PB
/WITH START ADS CHANGED TO 3465
/
/DROPPED IN THIS VERSION - CANT PUNCH FIELD 1
/
/
/ S.P.A.S.T.I.C. - TAPE 4
/MODIFY STARTING PROCEDURE TO GIVE INITIAL IOTS TO
/SOLENOID AND CLOCK
*4365
4365 6352 BEGINX,DSSL /DISABLE SOLENOID AND SCALAR
4366 6316 DSCF /DISABLE CLOCK ANDCLEAR FLAG
4367 7410 SKP
4370 4773 NJURCVR
/
/CERTAIN LAB-8 IOTS IN INITIAL RTN INTERFERE
/WITH STEPPING MOTOR IOTS M2F AND M4R (6331,6342)
/IF YOU USE A LAB-8 SYSTEM THESE STEPPING MOTOR IOT
/MUST BE CHANGED IN THE HARDWARE
/ERASE OFFENDING LAB-8 IOTS -
*4400
4400 7000 NOP
*4436
4436 7000 NOP
/PDP-5 AND PDP-9S ARE FORBIDDEN
/PROBLEM IS SPACE LIMITATIONS
/IN PAGE 000 AND PAGE 2600
/
/

```

```

/HALE ON INITIAL DIALOGUE, PDP-8S
/NO ROOM ON PAGE 2600 FOR
/MEMORY PARITY CHECK
/PDP-8S IS PROBABLY TOO SLOW ANYWAY
*4456
4456 7402 HLT
/
/HALE ON INITIAL DIALOGUE, PDP-5
/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 ON PAGE 0000
/
*4523
4523 7200 CLA /PATCH OUT INIT
/
/SET BUFFER LIMIT ON INITIALIZN
*4557
4557 4673 BUFEND-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 ARGS ARE IGNORED
/NEG ARGS=ERROR
/CLOCK UNIT=1-300TH SEC
/
*4675
BUFEND=.
4675 4540 ARGINT,PUSHJ / GET ANOTHER ARGUMENT
4676 1343 ARG
4677 5541 POPJ / NO ARG, RETURN WITHOUT SKIP
4700 4453 INTSGN,INTEGR / 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 SZA CLA
4710 4566 ERROR /ARG EXCEEDS 2 TO 23RD (APPROX #E6)
4711 1045 TAD FLAC+1
4712 7710 SPA 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,PUSHJ / FSET STARTS HERE
4720 4700 INTSGN
4721 5327 JMP SLIN / TL=0, IGNORE IT
4722 4352 JMS RNCH

```



```

4723 4543 PUSHF
4724 0044 FLAC
4725 4544 POPF
4726 6315 TIMELM / SET TIME LIMIT
4727 4540 SLIN,PUSHJ
4730 4675 ARGINT
4731 5340 JMP MIIV /      SL=0, IGNORE IT
4732 4750 JMS I LDIV2
4733 4352 JMS RNCH
4734 4543 PUSHF
4735 0044 FLAC
4736 4544 POPF
4737 6311 COUNTL
4740 4540 MIIV,PUSHJ
4741 4675 ARGINT
4742 5536 RETURN
4743 1046 TAD FLAC+2
4744 3747 DCA I LMSPD / MI IS SINGLE PREC
4745 5536 RETURN
/
4746 7751 M27,-27
4747 5372 LMSPD,MSPEED
4750 6757 LDIV2,DIV2
4751 5370 LRN,RUN
4752 0000 RNCH,0 / CHECK TIMER RUN STATUS
4753 1751 TAD I LRN
4754 7650 SMA CLA
4755 4566 ERROR / MUST BE OFF WHEN CHANGING LIMITS
4756 5752 JMP I RNCH
/
/ENTRY TO FOPR FUNCTION
/
/FOPR(0) - READ SC, TM WITHOUT STOPPING THEM
/FOPR(1) - STOP SC, TM, THEN READ THEM
/FOPR(2) - RESET AND START SC, TM
/FOPR(3) - RETURN TIMER STATUS, - FOR HI CT RATE,
/ 0 FOR TIMER RUNNING, + FOR TIMER STOPPED NORMALLY.
/FOPR(4) - RETURN MOTOR STATUS - INTEGER 0 THRU 15
/ 0 FOR ALL MOTORS STOPPED
/ ADD 1 FOR MTR 1 RUNNING, 2 FOR MTR 2 RUNNING, 4 FOR MTR 3
/ RUNNING, 8 FOR MTR 4 RUNNING
/FOPR(5) - STOP ALL MOTORS, RETURN FOPR=0
/ USE FOPR(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 FOPR,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,XFOPR
/
4772 5033 SOLND
4773 7300 NURCVR,CLA CLL / RESPONSE TO CNTRL-C OR RESTART AT 200
4774 4772 JMS I -2
4775 6314 DSCK

```

```

4776 5777 JMP I .+1
4777 2740 RECOVER / CHANGE TO 7600 TO JUMP TO DISC MONITOR
/NOTE THAT SUCH A CHANGE AFFECTS RESTART AT 0200 AS WELL
/AS CNTRL-C KEYBOARD SIGNAL
/IN SUCH EVENT USE 2740 AS RESTART ADDRESS AND
/REMEMBER THAT HARDWARE MAY NOT BE INITIALIZED
/
/
/
/ S.P.A.S.T.I.C. - TAPE 6
/RESET AND START SCALAR AND TIMER
/THE ONE-BIT PRESCALAR B4 SCALAR DATA BREAKS
/IS NOT RESET. ERROR=0,0,-1, OR +1 ON TOTAL COUNT
/THIS ERROR IS INSIGNIFICANT AND CANCELS OUT
/OVER A NUMBER OF INTENSITY DETERMINATIONS.
/
*5000
5000 0000 RESTART,0
5001 1704 TAD I LOCRUN
5002 7710 SPA CLA
5003 4566 ERROR / RESTART CANNOT BE CALLED AFTER HI CT RATE
5004 6002 IOF / UNTIL RUN IS CLEARED BY FSOL(0)
5005 4543 PUSHF
5006 6311 LCOL,COUNTL
5007 4544 POPF
5010 5360 LCOUNT,COUNT
5011 4543 PUSHF
5012 6315 LTIM,TIME
5013 4544 POPF
5014 5364 LTIME,TIME
5015 3704 DCA I LOCRUN
5016 3622 DCA I LBREAK
5017 6312 CCF/ENABLE CLOCK AND SCALAR
5020 6001 IOV
5021 5600 JMP I RESTART
5022 2600 LBREAK,BREAK
/
/FSOL-OPEN,CLOSE,OR READ SOLENOID
/ARG=0 CLOSE
/ARG=1 OPEN IT
/ARG=2 READ IT BUT DON'T CHANGE IT
/IN ANY EVENT, SOLENOID VALUE IS RETURNED
5023 4453 FSOL,INTEGR
5024 7110 CLL RAR
5025 7640 SZA CLA
5026 5231 JMP .+3
5027 7004 RAL
5030 4233 JMS SOLND
5031 1247 TAD SOLVAL
5032 5323 JMP DCFL2
/
/SOLENOID POSITIONING ROUTINE
/ENTER AC=0 OR 1 FOR CLOSED
/OR OPEN SOLENOID
/
5033 0000 SOLND,0
5034 7450 SVA
5035 5241 JMP .+4
5036 6351 ENSL / AC=1, OPEN SOLENOID
5037 6312 CCF / ALSO ENABLE CLOCK AS HI CT RATE PROTXN
5040 5244 JMP .+4
5041 6352 DSSL / AC=0, CLOSE SOLENOID

```

```

5042 7001 IAC
5043 3704 DCA I LOCRUN / CLEAR HI CT RATE FLAG
5044 3247 DCA SOLVAL / SAVE AC
5045 3622 DCA I LBREAK
5046 5633 JMP I SOLVD
5047 0000 SOLVAL,0 / STORE FOR FSOL(2)
/
/ THE FLWG RTNS ARE ON THE SAME PAGE AS REST
/ AND ARE MOVED IF RESTRT IS MOVED
/
/SCALAR AND TIMER READ OPERATIONS
/SCALAR CONTENTS PLACED AT S', TIMER AT T'
/
/F1-STOP THEM FIRST
/F1 DOES NOT CLEAR NEG RUN FLAG
5050 2704 F1,ISZ I LOCRUN
/MERGE WITH F0,DYNAMIC READ
5051 1302 F0,TAD SCKODE
5052 3061 DCA ADD
5053 4540 PUSHJ
5054 1437 GS1
5055 6002 IOF/FREEZE COUNT+TIME
5056 4407 FENT
5057 0610 FGET I LCOUNT
5060 2606 FSUB I LCOL
5061 7000 FNOR
5062 6430 FPUT I PT1
5063 0000 FEXT
5064 1303 TAD TMKODE
5065 3061 DCA ADD
5066 4540 PUSHJ
5067 1437 GS1
5070 4407 FENT
5071 0614 FGET I LTIME
5072 2612 FSUB I LTIM
5073 7000 FNOR
5074 6430 FPUT I PT1
5075 0000 FEXT
5076 6001 ION
/
/MERGE WITH F3, TIMER STATUS CHECK
/
5077 1704 F3,TAD I LOCRUN/SET FUNCTION SGN -,0,OR+
5100 3045 DCA FLAC+1/TO COINCIDE WITH SIGN OF RUN
5101 5323 JMP DCFL2
5102 2347 SCKODE,2347/ PACKED
5103 2447 TMKODE,2447/ ASCII
5104 5370 LOCRUN,RUN
/
/FTIM-RUN SCALAR AND TIMER
/FOR PRESET COUNT OR TIME
/INTERVAL,THEN READ
/
/ NOTE
/
/NEITHER FOPR(2) OR FTIM(...) OPENS 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 7120 CLL CML / DISPLAY LINK = 1 IN FTIM WAIT

```



```

5107 1704 TAD I LOCRUN
5110 7650 SVA CLA
5111 5307 JMP .-2/WAIT FOR PRESET
      /TABLE FOR FOPR
      /DO NOT CHANGE SEQUENCE OF LOCNS XFOPR-1 TO XFOPR+5
5112 5251 XFOPR,JMP F0
5113 5250 JMP F1
      /
      /F2, RESET AND START TIMER-SCALAR, RETURN STATUS
5114 4200 JMS RESTRT
5115 5277 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 3046 DCFL2,DCA FLAC+2
5124 5536 RETURN
      /CHECK MOTOR STATUS
      /FOPR(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 RETURN
5137 0000 MCHK,0 / CHECK 1 MOTOR, SAVE STATUS AT FLAC+2
5140 7100 CLL
5141 7640 SZA CLA
5142 7020 CML / SET LINK=1 IF RUNNING
5143 1046 TAD FLAC+2
5144 7004 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,0
5160 1757 TAD I DBLINC
5161 3374 DCA TDB1
5162 7101 CLL IAC
5163 1374 TAD TDB1
5164 3375 DCA TDB1+1
5165 2357 ISZ DBLINC
5166 2775 ISZ I TDB1+1
5167 5757 JMP I DBLINC
5170 2774 ISZ I TDB1 / INCR HI BITS
5171 5757 JMP I DBLINC
5172 7020 CML / SET LINK IF HI BITS OVERFLOW

```

```

5173 5757 JMP I DBLINC
5174 0000 TDB1,0
5175 0000 0
/
/
/
/
/      S.P.A.S.T.I.C. - TAPE 7
/FDRV ROUTINE
/INITIATES STEPPING MOTOR DRIVES
/ARGUMENTS A1 THRU A4=
/NBR OF STEPS FOR MOTORS 1-4
/ARGUMENTS ARE +OR- INTEGERS OR 0
/ZERO ARGUMENT LEAVES MOTOR UNAFFECTED
/A MOTOR CAN BE STOPPED FOR CERTAIN ONLY BY FOPR(S)
/
*5200
5200 6314 FDRV,DSCK / DISABLE CLOCK
5201 4543 PUSHF / INITIALIZE
5202 5260 LSTEP1
5203 4544 POPF / 3 LOCN COUNTERS
5204 5264 LSTEPN
5205 1263 TAD MFOUR
5206 3267 DCA ARGLIM / LIMIT 4 ARGS
5207 4453 LOOP,INTEGR/FLT PT AC TO INTEGER
5210 7450 SNA
5211 1045 TAD FLAC+1
5212 7650 SNA CLA
5213 5223 JMP ZADC
5214 1045 TAD FLAC+1
5215 7710 SPA CLA
5216 5230 JMP MADC
5217 4451 NEGATE/ARG=+, MAKE IT -
5220 1666 TAD I GTIOT
5221 2266 ISZ GTIOT
5222 5232 JMP SETIOT
5223 2266 ZADC,ISZ GTIOT / FLT PT AC=0, IGNORE IT
5224 2266 ISZ GTIOT
5225 2265 ISZ PTIOT
5226 2264 ISZ LSTEPN
5227 5242 JMP ZJMP
5230 2266 MADC,ISZ GTIOT /FLT PT AC=-
5231 1666 TAD I GTIOT
5232 3665 SETIOT,DCA I PTIOT/STORE MOTOR IOT
5233 2266 ISZ GTIOT
5234 2265 ISZ PTIOT
5235 1045 TAD FLAC +1
5236 3664 DCA I LSTEPN
5237 2264 ISZ LSTEPN
5240 1046 TAD FLAC+2
5241 3664 DCA I LSTEPN/STORE PULSE COUNT
5242 2264 ZJMP,ISZ LSTEPN / DOUBLE PREC INTEGER
5243 2267 ISZ ARGLIM
5244 7410 SKP
5245 5252 JMP MDLY/4TH ARG DONE
5246 4540 PUSHJ/NEXT ARG TO FLT PT AC
5247 1343 ARG
5250 7410 SKP / ARG LIST EXHAUSTED
5251 5207 JMP LOOP
5252 1372 MDLY,TAD MSPEED / SET DELAY B4
5253 3371 DCA MKT / NEXT MOTOR STEP
5254 3754 DCA I LBRK
5255 6312 CCF / ENABLE CLOCK

```

```

5256 6001 ION
5257 5536 RETURN
/
5260 5147 LSTEP1,STEP1
5261 5774 LCKTBL,CKTBL
5262 1553 LMIOTB,IOTBL
5263 7774 MFOUR,-4
5264 5147 LSTEPN,STEP1 / THREE
5265 5774 PTIOT,CKTBL / VARIABLE
5266 1553 GTIOT,IOTBL / POINTERS
5267 0000 ARG LIM,0
/
/CLOCK INTERRUPT SERVICE
/INTERRUPT RATE 300 HZ
/GIVEN FIRST PRIORITY
5270 1754 CASKVC,TAD I LBRK/GET SCALER DATA BREAK COUNT
5271 3357 DCA TCK
5272 3754 DCA I LBRK/ZERO THE SCALER
5273 1357 TAD TCK
5274 0101 AND P7700
5275 7640 SZA CLA/TEST FOR HIGH RATE
5276 5347 JMP HIKT
5277 6312 CFLG,CCF/ENABLE CLOCK AND SCALER
5300 1370 TAD RUN
5301 7640 SZA CLA/SOFTWARE SCALER-TIMER RUNNING?
5302 5317 JMP MTRCHK/NO
5303 7100 CLL
5304 1357 TAD TCK
5305 1362 TAD COUNT+2
5306 3362 DCA COUNT+2
5307 7430 SZL
5310 2361 ISZ COUNT+1
5311 7410 SKP
5312 2370 ISZ RUN/SCALER LIMIT REACHED
5313 4756 JMS I LDBLI/INCR TIME VALUE
5314 5365 TIME+1
5315 7430 SZL
5316 2370 ISZ RUN/TIMER LIMIT REACHED
5317 2371 MTRCHK,ISZ MKTK/MOTOR PULSE DUE?
5320 5755 JMP I LBACK/NO
5321 1372 TAD MSPEED/YES
5322 3371 DCA MKTK
5323 1263 TAD MFOUR
5324 3357 DCA TCK
5325 1373 TAD LM1KT
5326 3335 DCA LMNKT
5327 1374 TAD LM1IOT
5330 3375 DCA LMNIOT
5331 1735 MTLOOP,TAD I LMNKT/MOTOR PULSE LOOP
5332 7650 SVA CLA
5333 5341 JMP NOPLS/NTH MOTOR IDLE
5334 4756 JMS I LDBLI/INCR MOTOR STEP COUNT
5335 5147 LMNKT,STEP1/VARIES
5336 1775 TAD I LMNIOT
5337 3340 DCA .+1
5340 7000 NOP/MOTOR PULSE IOT
5341 2375 NOPLS,ISZ LMNIOT
5342 2335 ISZ LMNKT
5343 2335 ISZ LMNKT
5344 2357 ISZ TCK/COUNT 4 MOTORS
5345 5331 JMP MTLOOP
5346 5755 JMP I LBACK/ RETURN TO INTRPX

```



```

5347 6352 HIKT,DSSL/CLOSE SOLENOID
5350 3776 DCA I LSOLV
5351 1347 TAD HIKT/RATE EXCEEDS 38 KHZ
5352 3370 DCA RUN/SET FLAG NEGATIVE
5353 5277 JMP CFLG/GO SVC MOTORS
5354 2600 LBRK,BREAK
5355 2606 LBACK,BACK
5356 5157 LDBLI,DBLINC
5357 0000 TCK,0
5360 2000 COUNT,2000 / SOFTWARE SCALER
5361 6000 6000 / SET COUNT HIGH - VALUE AT LOAD TIME
5362 0000 0
5363 0000 0 / 4 WORD
5364 0027 TIME,27/SOFT WARE TIMER
5365 0000 0 / DO NOT CHANGE EXPNT
5366 0000 0
5367 0000 0 / REQD BY 4 WORD
5370 0001 RUN,1/SOFTWARE SC-TM RUN INDICATOR
/      SET 0 WHEN RUNNING
/      SET 1 OR 2 WHEN STOPPED
/      SET LARGE NEG INTEGER (DSSL) FOR XS CT RATE
/
5371 7777 MTKT,-1 /VARIES
5372 7777 MSPEED,-1 / SET BY FSET-HI SPEED IN EFFECT AT LOAD
5373 5147 LMIKT,STEP1
5374 5774 LMIIOT,CKTBL
5375 5774 LMNIOT,CKTBL/VARIES
5376 5047 LSOLV,SOLVAL
/
/
/
/      S.P.A.S.T.I.C. - TAPE 8
/      TABLE OF MOTOR IOTS WITH PROPER DIRECTION CHOSEN
*5774
5774 7000 CKTBL,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 INTRPX,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 COUNTL,30 / COUNT LIMIT SET AT 1000 AT LOAD TIME
6312 7777 7777
6313 7014 7014
6314 0000 0
6315 0027 TIMELM,27 / TIME LIMIT SET AT 4096 SEC AT LOAD TIME
6316 7324 7324
6317 0000 0
6320 0000 0
/
*PRNT8-1
7526 5757 JMP I DLIB /LIBRARY EXIT, 4K
*DLIB
7557 4773 NURCUR /4K POINTER (CLEARS HARWARE)

```

/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

*LINE0+4

0104 4023 4023 / S
0105 2001 2001 /PA
0106 2324 2324 /ST
0107 1103 1103 /IC
0110 5467 5467 /7
0111 6640 6640 /6

*RLIB

0125 4773 VURCVR /NEW EXIT FROM LIBRARY (CLEARS HARDWARE)

FIELD 0

*DLIB

7557 0120 DLIB8 /RESTORE AS IN 8K OVERLAY (CHANGED EARLIER THIS PATCH)

/

ADD	0061	GIOT	5266	MLOOP	5331
ARG	1303	HIKT	5347	MTRC4K	5317
ARGINI	4675	ILGL	0634	M27	4746
ARGLIM	5267	INTRPT	2603	MS	0120
BACK	2606	INTRPK	6172	NOFLS	5341
BEGINX	4365	INTSGV	4700	VURCVR	4773
BRANCH	4771	IOTBL	1553	PRNFB	7527
BREAK	2600	LBACK	5355	PTIOT	5265
BUFEND	4675	LBREAK	5022	PTI	0030
CFLG	5277	LBKK	5354	F7600	0104
CHAR	0066	LCKSVC	2654	F7700	0101
CKSVC	5270	LCATBL	5261	RECOVR	2740
CKTBL	5774	LCOL	5006	RESTRT	5000
COINT	5360	LCCOUNT	5010	RLIB	0125
COINTL	6311	LDBLI	5356	RNCH	4752
C260	0113	LDI2	4750	RUN	5370
DBLINC	5157	LIVE0	0100	SAVACK	0003
DCFL2	5123	LMIOTB	5262	SAVLK	2601
DIV2	6757	LMNIOT	5375	SCCODE	5102
DLIB	7557	LMNKT	5335	SEIOT	5232
DLIB8	0120	LMSPD	4747	SLIN	4727
ERRORS	2725	LMIOT	5374	SOLVD	5033
EVAL	1613	LMIKT	5373	SOLVAL	5047
EXI	0040	LOCRUN	5104	START	0177
FAND	1142	LOOP	5207	STEP1	5147
FDRV	5200	LRN	4751	STEP2	5151
FLAC	0044	LSOLV	5376	STEP3	5153
FNTABF	0374	LSTEPV	5264	STEP4	5155
FNTABL	2165	LSTEP1	5260	TCK	5357
FOPR	4757	LTIL	5012	ID31	5174
FSET	4717	LTIME	5014	TIME	5364
FSOL	5023	MADC	5230	TIMELM	6315
FTIM	5105	MCHK	5137	TMCODE	5103
F0	5051	MCOMMA	1353	XFOPR	5112
F1	5050	MDLY	5252	ZADC	5223
F3	5077	MFOUR	5263	ZJMP	5242
F4	5125	MIIN	4740		
F5	5117	MSPEED	5372		
GS1	1437	MTKT	5371		

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