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DECUS NO.	8-642
TITLE	AUTOCO - AUTOCORRELATION FOR POOR PEOPLE (WITHOUT EAE)
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DATE	June 19, 1973
SOURCE LANGUAGE	XPAL

AUTOCO (with EAE simulator)

Overall Program Design

The program seeks to obtain an autocorrelation function on a string of data of 512 points or less by computing a Pearson product-moment correlation coefficient between elements of the string and those same elements "delayed" with respect to themselves. This particular type of analysis may play an important role in the evaluation of random or quasi-random functions which may contain periodic components, for example, EEG activity coincident with repeated stimuli. (See the following: Lee, Y.W., Statistical Theory of Communication, New York: John Wiley and Sons, Inc., (1960) or Dern, H., and Walsh, J.B., Analysis of complex waveforms, in Physical Techniques in Biological Research, Wm. L. Nastuk, editor, New York: Academic Press (1963) Volume 6.)

The figure below provides an example of the effectiveness of this technique. The top tracing shows an example of a sample of quasi-random noise extending from 400 through 10,000 Hz, and an associated autocorrelation function based upon 200 points of that sample. The tracings on the bottom are another example of the noise mixed with a 500 Hz sinusoid at 0 dB S/N ratio. The autocorrelation function on the right clearly shows periodicity related to the fundamental component of the 500 Hz element, though its presence is not apparent in the input data.

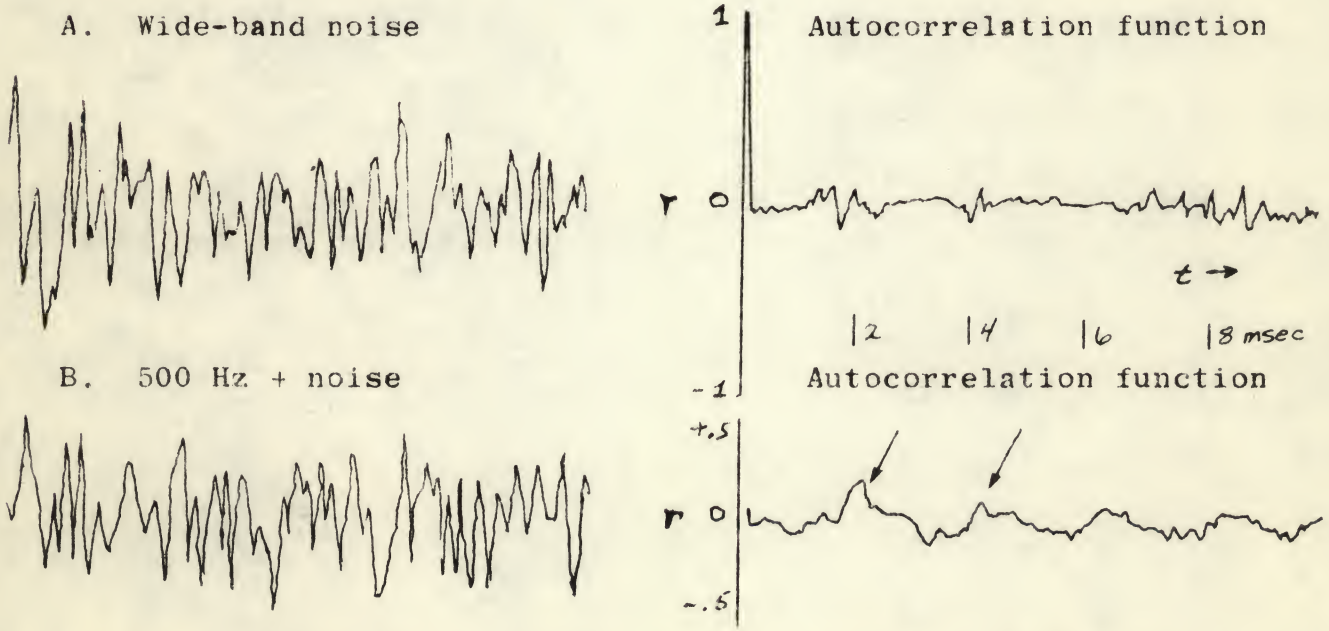


Figure 1. Examples of autocorrelation functions based upon 200 data points with 100 microsecond bin-width. The magnitude of the autocorrelation function excursions is determined in part by S/N ratio, sample size (re: period of the component which is being sought), etc.

The data for which this program was designed are typically gathered on our 138E A/D converter. Data are input to the computer in a 10-bit signed format. Since our display is limited to a 10-bit unsigned format (it is a VC8/I), the input data are converted to unsigned numbers having a mean at 1000_8 and a range from 0000_8 through 1777_8. It is in this form that we compute means, etc., of data --- viz., unsigned positive numbers ranging from 0-1777 with a nominal mean at 1000_8. This is schematized in the figure below.

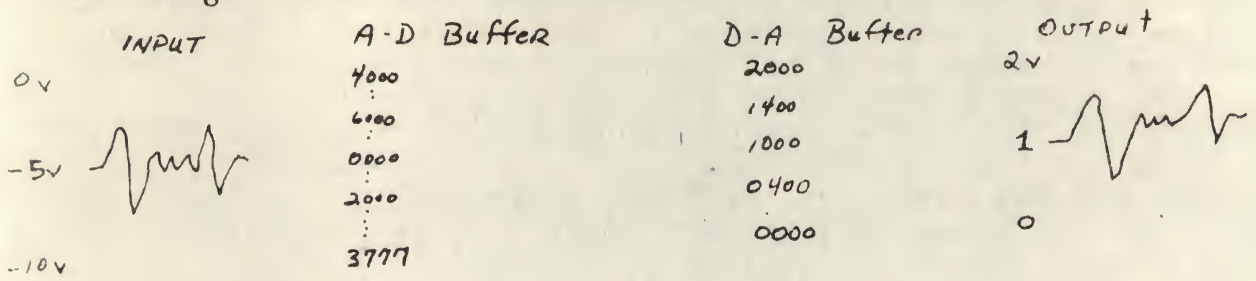


Figure 2. Representation of data suitable for input to the autocorrelator.

It is not necessary for a user to have this particular type of system, only that he have his data in the format shown on the right side of the figure prior to use of the autocorrelator.

The steps for the correlation are as follows.

1. The "computation" formula for the Pearson r is given as:

$$r = \frac{\sum XY - \frac{\sum X \sum Y}{N}}{\sqrt{\left[\sum X^2 - \frac{(\sum X)^2}{N}\right]\left[\sum Y^2 - \frac{(\sum Y)^2}{N}\right]}}$$

X AND Y ARE SCORES IN TWO DISTRIBUTIONS

2. But since the X and Y distributions are based on the same data:

$$r = \frac{\sum XY - \frac{(\sum X)^2}{N}}{\sum X^2 - \frac{(\sum X)^2}{N}}$$

3. In the zero time delay condition, the expression reduces to:

$$r = \frac{\sum X^2 - \frac{(\sum X)^2}{N}}{\sum X^2 - \frac{(\sum X)^2}{N}} = \frac{N\sum X^2 - (\sum X)^2}{N\sum X^2 - (\sum X)^2} = 1.000$$

4. And for any other condition:

$$r = \frac{N\sum XY - (\sum X)^2}{N\sum X^2 - (\sum X)^2}$$

Since working with 3 or 4 digits to the right of the binary point is troublesome, the working formula used here further modifies the coefficient by adding a baseline of 1000_8 (to accomodate the display) after multiplying the coefficient by 1000_8 to arrive at "r"values running from 1777_8 (for a +1.000) through 1000_8 (for a 0.000) to 0001 (for -1.000). There is an 0.2% rounding error inherent in this but it should be satisfactory for most applications.

Program flow

This might be followed best by referral to the program listing. Generally, the procedure is as follows:

1. Clear core and setup counters, etc.
2. Read 4 blocks of data into locations 4000-4777 from unit 1.
3. Find the smallest datum point and then subtract this (X_{small}-1) from all data points to arrive at the smallest mean without affecting the range and without having any zeros. (This step saves much computation time.)
4. Get SUMX
5. Get $(SUMX)^2$
6. Get N*SUM X^2
7. Form denominator (which stays constant for this set of data)
8. Get N*SUM XY (where Y is actually X "delayed" by 0,...,n bins)
9. Form numerator (which changes with each "delay")
10. Obtain correlation and store at location 5000,...,5777.
11. Increment "delay" value and go back to 8 if not finished.
12. If done, display data and correlation result.
13. Search switch register. If bit 11=1, store r on unit 2, using next available 4 blocks. If bit 0=1, get next data from unit 1 and recycle through program.

CRITICAL LOCATIONS

All user communication with program is via switch register. As such, the following locations may be of interest to him.

1. Number of data blocks (at 128_{10} words each): The program assumes that the user has 512_{10} data points, or four (4) blocks of data on the source tape. If he has less than that, he may change the following locations to accomodate for the size of his field:

Location	Normal	Mnemonic
0011	0004	# of blocks to be read/written
0476	1204	Read function word, change last six bits to appropriate # blks.
0453	2404	Write function word, change last six bits as above

2. Start of analysis -- is assumed to be coincident with the first data point. You have the option of picking a new start point, e.g., ½-way down the sample.

Location	Normal	Mnemonic
0021	4000	Rpoint (lst point restoring value)

If, for example, stimulus artifacts occupy the first few bins of your data, you may wish to set the starting point at 4100. The display resulting from this change in starting point will accomodate itself to it, and will locate the function over the data from which the function was derived.

If you wish to change the starting point, keep the following in mind:

3. The number of points may always be less than 512, but the total number plus the starting point may never exceed 4777! (or the end point of your data if you read in less than 4 blks) The 4777 is the address of the last location in which data are to be stored. If you exceed this, you'll include zeros in your analysis --- a time consuming process. The counter is located as follows:

Location	Normal	Mnemonic
0023	7000	Rcount (2's complement of number of points in analysis)

4. The starting block numbers for reading (location 0010) and writing (location 0012) may be changed freely, but the program assumes source data are on unit 1 and the autocorrelation functions will be stored on unit 2. Change the function word at 0453 (2404) to 1404 if you wish to store the functions on unit 1 (or any other by setting #404).

USE and ABUSE

1. Loading and saving: You may load this program with a 1-pass binary loader. Core requirements are 0-1777, and starting address is 0200.

2. After program is loaded, you may proceed as follows:

   A. Put source data on tape unit number 1.
   B. Put blank (marked) destination tape on unit number 2.
   C. Set new RPOINT and RCOUNT values, if desired.
   D. Load the starting address 0200
   E. and press START

   The program will run automatically until the function is completed for one-half of the total number of points in the sample, which corresponds to positive delay times re: the midpoint of the sample used for the analysis. In any non-random data, the continuation of the analysis would result in a mirror-image function corresponding to the"negative" delay times, and is unnecessary for most applications.

   The entire set of data read in will then be displayed, and the autocorrelation function will be superimposed upon the data, located on the x-axis at a point corresponding to the starting point of the analysis.

   F. If you wish to automatically store the data and proceed to obtain the next data, set the switch register to 4001.
   G. If you wish to store the data, but return to the display, set the switch register to 0001. You may start the next analysis by restarting the program at 0200.

   Using F above, you may put several samples of data on a source tape, start the first analysis, and go home --- hopefully to find that several hundred functions have been completed by the morning.

3. The range permitted is $0000\text{-}1777_8$ for input data, but remember that the smaller the range, the shorter the computation time. In addition, there can be no ZEROS as data points, for computing 0^2 is very time-consuming!

4. Our "means" are normally at 1000_8 because of the D/A system, but any non-zero mean less than 1777_8 should be satisfactory. The mean will not affect the autocorrelation output.

5. Examples of the use of the program are attached. On the right in the figure, you may see five response means for stimuli presented to the auditory system at rates of 2000, 1000, 500, 250, and 125 pulses per second, respectively.

   The question we have regarding the responses is: "Is the cyclical activity shown between the vertical lines intersecting all the tracings related to the stimulus fundamental period?"

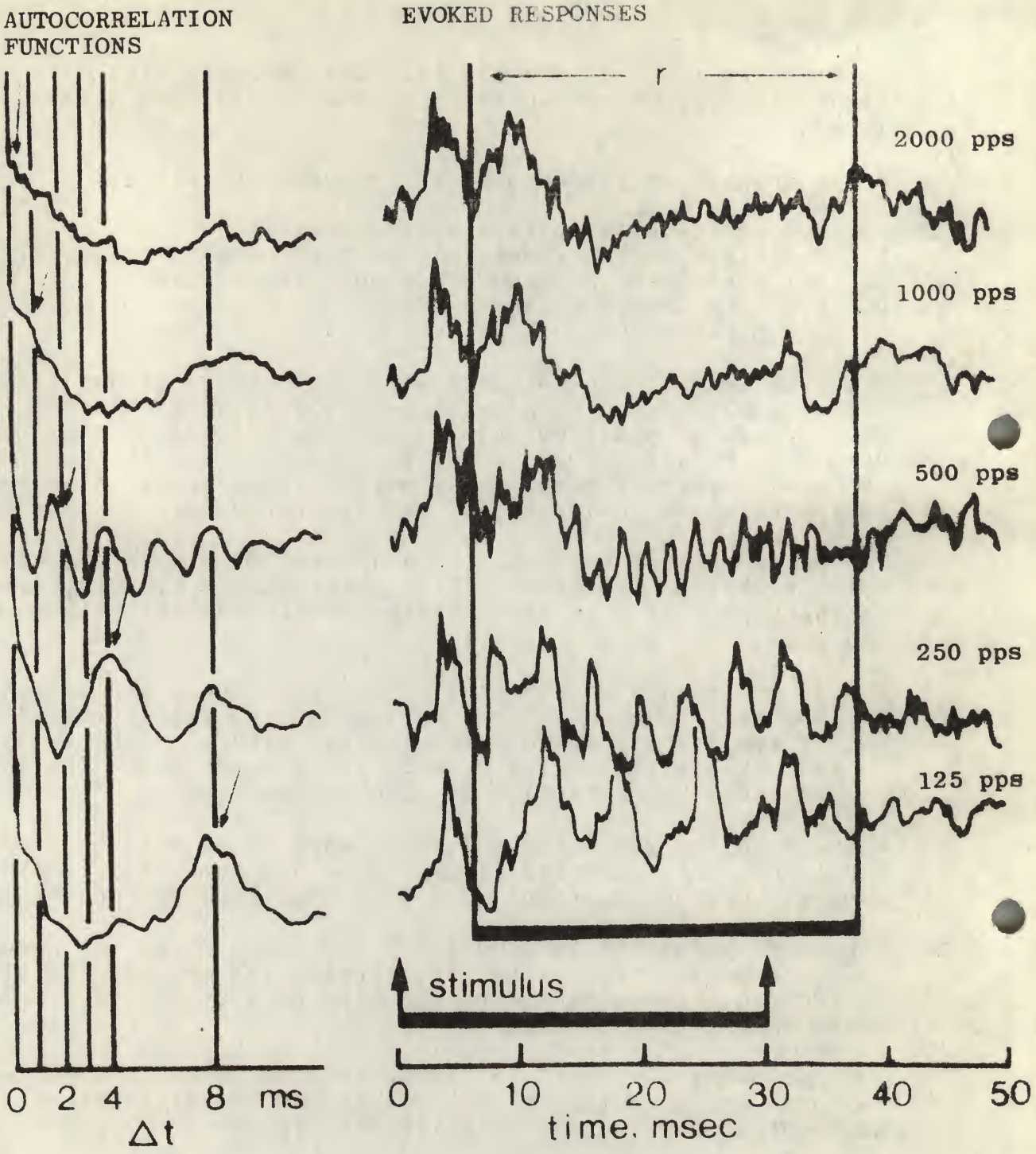


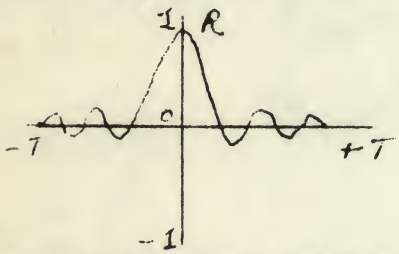
Figure 3. Examples of autocorrelation functions for brainstem following activity.

The autocorrelation functions corresponding to the data in the right column are shown in the left column. Normally, a relative or absolute maximum or minimum in the function relates to the period of some periodic event in the data; and zero axis crossings in the functions may also be interpretable in the same fashion. The arrows in each section of the autocorrelation functions show the anticipated locus of the period of the cyclical activity in the data corresponding to each function. As is apparent, one-to-one following activity was obvious for 250 and 125 pulses per second, but not for higher rates of stimulation.

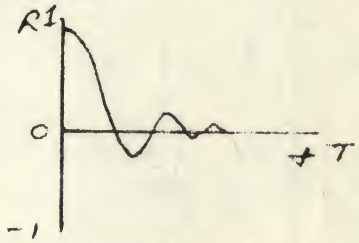
To familiarize himself with the use of the program, the user may prefer to analyze sinusoids or other repetitive stimuli in his laboratory with known temporal characteristics.

Misc

Autocorrelation functions are often displayed as indicated on the left below, viz., with "+" and "-" delay times relative to a sample starting point. In a periodic signal, these should be mirror images, thus, in the present program, only the "+" delay results are computed and displayed. This is indicated on the right.



Conventional plotting



Present use

About time --- the temporal sensitivity of the autocorrelation function output is identical to the sampling rate for the data which are submitted to analysis. If you are using a 100 microsecond/bin sample rate, then the points of the analysis will be equivalent to time delays of 100 microseconds. This is so because the delays are taken in one-bin intervals. If you plot your data on a conventional XY plotter and then plot the analysis results without changing the X-axis sensitivity, the time scale for the two displays will be identical.

Computation time --- this ranges from less than a minute to 17 minutes. It depends upon the number of points submitted to analysis and the absolute value of those points (squaring large numbers takes longer). You may wish to use only 32 or 64 points initially, until you have some facility with the program.

```
0001                    DXL=6053
0002                    DYL=6063
0003                    *0010
0004  0010  0000  BEGBLK, 0000   READ BLK NEXT (UNIT #1)
0005  0011  0004  BLKS,   0004   # BLKS TRANSFERRED
0006  0012  0000  WBLK,   0000   WRITE BLK NEXT (UNIT #2)
0007  0013  0000  CORCNT, 0000   # OF r VALUES (½ # points)
0008  0014  0000  SIGN,   0000   FOR SIGNED SUBTRACTION
0009  0015  0000  NEGATE, 0000   SIGN FOR r
0010  0016  1000  K1000,  1000
0011  0017  0777  K777,   0777
0012
0013                    *0020
0014  0020  4000  POINT,  4000
0015  0021  4000  RPOINT, 4000   1st DATA POINT (May be changed)
0016  0022  7000  COUNT,  7000
0017  0023  7000  RCOUNT, 7000   2's comp of N  (May be changed)
0018  0024  5000  CORR,   5000
0019  0025  5000  RCORR,  5000   1st STORAGE LOCATION FOR r
0020  0026  0000  DPOINT, 0000   Incremented to cause "delay"
0021  0027  0000  CHECK,  0000   Limit of delay
0022  0030  0000  DELAY,  0000   Increment and added to DPOINT
0023
0024  0031  7000  RESET, NOP
0025  0032  7300  CLA CLL        Reset pointer and counter
0026  0033  1021  TAD RPOINT
0027  0034  3020  DCA POINT
0028  0035  1023  TAD RCOUNT
0029  0036  3022  DCA COUNT
0030  0037  3151  DCA XAXIS
0031  0040  5431  JMP I RESET
0032
0033  0041  7000  SETCOR, NOP
0034  0042  7300  CLA CLL        Reset Storage for r
0035  0043  1025  TAD RCORR
0036  0044  3024  DCA CORR
0037  0045  5441  JMP I SETCOR
0038
0039  0046  7000  CORE, NOP
0040  0047  4153  JMS XSET       Clears 2000₈ locations beginning
0041  0050  3420  DCA I POINT    at 4000, and going through 5777.
0042  0051  3424  DCA I CORR
0043  0052  2020  ISZ POINT
0044  0053  2024  ISZ CORR
0045  0054  2022  ISZ COUNT
0046  0055  5050  JMP .-5
0047  0056  4031  JMS RESET
0048  0057  3030  DCA DELAY
0049  0060  5446  JMP I CORE
0050
0051  0061  7000  LIMIT, NOP     Sets "delay" = RPOINT+N  at its limit.
0052  0062  1023  TAD RCOUNT     Caution!!!
0053  0063  7041  CIA            This can never be greater than 4777!
```

AUTOCORRELATION ROUTINE MAY,1973 T. GLATTKE
RECORD 1

```
0054  0064  1021  TAD RPOINT
0055  0065  7041  CIA
0056  0066  3027  DCA CHECK
0057  0067  5461  JMP I LIMIT
0058
0059  0070  7000  HALF, NOP
0060  0071  7300  CLA CLL
0061  0072  1023  TAD RCOUNT
0062  0073  7041  CIA
0063  0074  7110  CLL RAR
0064  0075  7041  CIA
0065  0076  3013  DCA CORCNT
0066  0077  5470  JMP I HALF
0067
0068
0069  0100  0000  SUM1,0000
0070  0101  0000  SUM2,0000
0071  0102  0000  SUM3,0000
0072  0103  0000  SUM4,0000
0073  0104  0000  OR1,0000
0074  0105  0000  OR2,0000
0075  0106  0000  OR3,0000
0076  0107  0000  OR4,0000
0077  0110  0000  X1,0000
0078  0111  0000  X2,0000
0079  0112  0000  X3,0000
0080  0113  0000  X4,0000
0081  0114  0000  Y1,0000
0082  0115  0000  Y2,0000
0083  0116  0000  Y3,0000
0084  0117  0000  Y4,0000
0085  0120  0000  SMX21,0000
0086  0121  0000  SMX22,0000
0087  0122  0000  SMX23,0000
0088  0123  0000  SMX24,0000
0089  0124  0000  DENOM1,0000
0090  0125  0000  DENOM2,0000
0091  0126  0000  DENOM3,0000
0092  0127  0000  DENOM4,0000
0093  0130  0000  XY1,0000
0094  0131  0000  XY2,0000
0095  0132  0000  XY3,0000
0096  0133  0000  XY4,0000
0097
0098  0134  0472  READ, GET
0099  0135  0534  SUMX, GETX
0100  0136  0600  MUL, MPY
0101  0137  1000  SUMX2, GETX2
0102  0140  1122  DENOM, DIVIS
0103  0141  0716  SUBTR, MINUS
0104  0142  1400  XPROD,XYPROD
0105  0143  1600  NUMER,DIVID
0106  0144  0000  TALLY,0000
0107  0145  0000  TFLAG,0000
```

Sets r counter = $\frac{1}{2}$ number of points.
To get full function, insert NOPs in 73,74,75.
In this mode, only the "+" delay times are used.

Registers for $(\Sigma X)^2$

Accumulators for multiply and subtraction routines

Registers for $N(\Sigma X^2)$

Registers for $N(\Sigma X^2) - (\Sigma X)^2$

Registers for $N(\Sigma XY)$

Indirect address tags and misc stuff

```
0108  0146  0002  INCR,0002
0109  0147  1200  RW,RWTAPE
0110  0150  4000  KPOINT,4000
0111  0151  0000  XAXIS, 0000
0112  0152  3000  KEEP, 0000
0113  0153  7000  XSET, NOP
0114  0154  1161  TAD K7
0115  0155  3022  DCA COUNT
0116  0156  1162  TAD K2
0117  0157  3020  DCA POINT
0118  0160  5553  JMP I XSET
0119  0161  7000  K7, 7000
0120  0162  4000  K2,4000
0121
```

```
0001                    *0200
0002  0200  7300  START, CLA CLL
0003  0201  4041  JMS SETCOR       Restore r pointer
0004  0202  4046  JMS CORE         Clear core from 4000-5777
0005  0203  4070  JMS HALF         Set r counter to ½ N (optional)
0006  0204  4534  JMS I READ       Get DATA from tape unit #1
0007  0205  4031  JMS RESET        Set pointers and counters
0008  0206  4041  JMS SETCOR       Restore r pointer
0009  0207  4153  JMS XSET         Set counter for 512₁₀ points
0010  0210  1420  TAD I POINT
0011  0211  7041  CIA
0012  0212  3027  DCA CHECK
0013  0213  1420  TAD I POINT
0014  0214  1027  TAD CHECK        Find smallest datum point (Xs)
0015  0215  7500  SMA
0016  0216  5223  JMP .+5
0017  0217  7300  CLA CLL          NOTE NOTE NOTE-----THERE CAN BE
0018  0220  1420  TAD I POINT      NO ØØØØs IN YOUR SAMPLE!!!!
0019  0221  7041  CIA
0020  0222  3027  DCA CHECK
0021  0223  7300  CLA CLL
0022  0224  2020  ISZ POINT
0023  0225  2022  ISZ COUNT
0024  0226  5213  JMP .-13
0025  0227  4153  JMS XSET
0026  0230  1027  TAD CHECK
0027  0231  7001  IAC              Subtract (Xs-1) from all data
0028  0232  3027  DCA CHECK        so that the mean is reduced to
0029  0233  1420  TAD I POINT      smallest possible value, but
0030  0234  1027  TAD CHECK        the variance is not disturbed.
0031  0235  3420  DCA I POINT
0032  0236  2020  ISZ POINT
0033  0237  2022  ISZ COUNT
0034  0240  5233  JMP .-5
0035  0241  4031  JMS RESET
0036  0242  4061  JMS LIMIT
0037
0038  0243  4535  JMS I SUMX       Puts ΣX into SUM1 ... SUM3
0039
0040  0244  4536  JMS I MUL        Puts (ΣX)² into SUM1 ... SUM3
0041  0245  1104  TAD OR1
0042  0246  3100  DCA SUM1
0043  0247  1105  TAD OR2
0044  0250  3101  DCA SUM2
0045  0251  1106  TAD OR3
0046  0252  3102  DCA SUM3
0047  0253  1107  TAD OR4
0048  0254  3103  DCA SUM4
0049
0050  0255  7300  CLA CLL
0051
0052  0256  4537  JMS I SUMX2      Puts NΣX² into SUMX21 ... SUMX23
0053
```

```
0054  0257  4540  JMS I DENOM      Puts N Σ(x²) - (Σx)² into DENOM1 ...
0055                                    thru DENOM3
0056  0260  7300  CLA CLL
0057
0058  0261  4031  JMS RESET
0059  0262  3030  DCA DELAY
0060
0061  0263  4542  CROSPD, JMS I XPROD  Puts NΣXY into XY1 ... XY3
0062
0063  0264  7300  CLA CLL,
0064
0065  0265  4543  JMS I NUMER      Forms 1000 [NΣxy - (Σx)(Σy)] in OR1 ...
0066                                    thru OR4
0067  0266  3144  DCA TALLY
0068
0069  0267  7300  CLA CLL
0070
0071  0270  1104  DOCO, TAD OR1
0072  0271  3110  DCA X1
0073  0272  1105  TAD OR2
0074  0273  3111  DCA X2
0075  0274  1106  TAD OR3
0076  0275  3112  DCA X3
0077  0276  1107  TAD OR4
0078  0277  3113  DCA X4          Division is by repeated subtraction
0079  0300  1124  TAD DENOM1
0080  0301  3114  DCA Y1
0081  0302  1125  TAD DENOM2
0082  0303  3115  DCA Y2
0083  0304  1126  TAD DENOM3
0084  0305  3116  DCA Y3
0085  0306  1127  TAD DENOM4
0086  0307  3117  DCA Y4
0087  0310  4541  JMS I SUBTR
0088  0311  1014  TAD SIGN        Done?
0089  0312  7650  SNA CLA
0090  0313  5321  JMP .+6         Yes
0091  0314  7300  CLA CLL
0092  0315  1144  TAD TALLY
0093  0316  7001  IAC
0094  0317  3144  DCA TALLY
0095  0320  5270  JMP DOCO
0096  0321  7300  CLA CLL
0097  0322  1015  TAD NEGATE      Get sign
0098  0323  7440  SZA
0099  0324  5332  JMP .+6
0100  0325  7300  CLA CLL         Form + correlation value
0101  0326  1144  TAD TALLY
0102  0327  1017  TAD K777
0103  0330  3144  DCA TALLY
0104  0331  5337  JMP .+6
0105  0332  7300  CLA CLL
0106  0333  1144  TAD TALLY       form (-) correlation value
0107  0334  7041  CIA
```

```
0108  0335  1016  TAD K1000
0109  0336  3144  DCA TALLY
0110  0337  1144  TAD TALLY
0111  0340  3424  DCA I CORR
0112  0341  2024  ISZ CORR
0113  0342  2030  ISZ DELAY
0114  0343  3015  DCA NEGATE
0115  0344  2013  ISZ CORCNT
0116  0345  5263  JMP CROSPD
0117  0346  7300  CLA CLL
0118  0347  3145  DCA TFLAG
0119  0350  5751  JMP I NEXT
0120  0351  0400  NEXT, 0400
0121
```

```
0001                    *0400
0002  0400  7300  DISPLY, CLA CLL
0003  0401  4307  JMS RESETD
0004  0402  1151  TAD XAXIS
0005  0403  6053  DXL
0006  0404  7200  CLA
0007  0405  1420  TAD I POINT
0008  0406  6063  DYL
0009  0407  7200  CLA
0010  0410  2020  ISZ POINT
0011  0411  1151  TAD XAXIS
0012  0412  1146  TAD INCR
0013  0413  3151  DCA XAXIS
0014  0414  2022  ISZ COUNT
0015  0415  5202  JMP .-13
0016  0416  7300  CLA CLL
0017  0417  4317  JMS RESETC
0018  0420  1151  TAD XAXIS
0019  0421  6053  DXL
0020  0422  7200  CLA
0021  0423  1420  TAD I POINT
0022  0424  7010  RAR
0023  0425  6063  DYL
0024  0426  7200  CLA
0025  0427  2020  ISZ POINT
0026  0430  1151  TAD XAXIS
0027  0431  1146  TAD INCR
0028  0432  3151  DCA XAXIS
0029  0433  2022  ISZ COUNT
0030  0434  5220  JMP .-14
0031  0435  7300  CLA CLL
0032  0436  7604  LAS
0033  0437  7010  RAR
0034  0440  7620  SNL CLA
0035  0441  5200  JMP DISPLY
0036
0037  0442  7300  CLA CLL
0038  0443  1145  TAD TFLAG
0039  0444  7440  SZA
0040  0445  5200  JMP DISPLY
0041  0446  7001  IAC
0042  0447  3145  DCA TFLAG
0043  0450  1012  TAD WBLK
0044  0451  3254  DCA OUT
0045  0452  4547  JMS I RW
0046  0453  2404  2404
0047  0454  0000  OUT, 0
0048  0455  5000  5000
0049  0456  0457  .+1
0050  0457  1012  TAD WBLK
0051  0460  1011  TAD BLKS
0052  0461  3312  DCA WBLK
0053  0462  7300  CLA CLL
```

Displays data and r function on VC8/I.

Note, XAXIS is incremented by 2 to accomodate full-width display.

User may wish to modify to put data on left and e.g., r on right.

Displays contents of 4000-4777. (Data)

Displays contents of 5000 and up, to a limit of 5000 + N;, and locates the display over the data at point where analysis is initiated.

Bit 11 = 1?

No, continue with display

Yes, have data been stored?

No, raise tape flag

and put contents of 5000-5777 in

next available block on Unit #2.

```
0054  0463  7604  LAS
0055  0464  7004  RAL
0056  0465  7620  SNL CLA
0057  0466  5200  JMP DISPLY
0058  0467  5670  JMP I XSTART
0059  0470  0200  XSTART, 0200
0060  0471  7000  NOP
0061
0062  0472  7000  GET, NOP
0063  0473  1010  TAD BEGBLK
0064  0474  3277  DCA INB
0065  0475  4547  JMS I RW
0066  0476  1204  1204
0067  0477  0000  INB,0
0068  0500  4000  4000
0069  0501  0502  .+1
0070  0502  1010  TAD BEGBLK
0071  0503  1011  TAD BLKS
0072  0504  3010  DCA BEGBLK
0073  0505  7300  CLA CLL
0074  0506  5672  JMP I GET
0075
0076  0507  7000  RESETD, NOP
0077  0510  7300  CLA CLL
0078  0511  1150  TAD KPOINT
0079  0512  3020  DCA POINT
0080  0513  1333  TAD DXNT
0081  0514  3022  DCA COUNT
0082  0515  3151  DCA XAXIS
0083  0516  5707  JMP I RESETD
0084  0517  7000  RESETC, NOP
0085  0520  7300  CLA CLL
0086  0521  1025  TAD RCORR
0087  0522  3020  DCA POINT
0088  0523  4070  JMS HALF
0089  0524  1013  TAD CORCNT
0090  0525  3022  DCA COUNT
0091  0526  1021  TAD RPOINT
0092  0527  7004  RAL
0093  0530  3151  DCA XAXIS
0094  0531  5717  JMP I RESETC
0095  0532  4000  K4, 4000
0096  0533  7000  DXNT,7000
0097
```

After data transfer, check bit Ø

Bit Ø=1?
No, go to display
Yes, go to program start

Entry to tape read routine,

gets next 4 blocks from Dectape #1

and puts data into loc 4000-4777

```
0001  0534  7000  GETX, NOP
0002  0535  7300  CLA CLL
0003  0536  3100  DCA SUM1
0004  0537  3101  DCA SUM2
0005  0540  3102  DCA SUM3
0006  0541  3103  DCA SUM4
0007  0542  4031  JMS RESET
0008  0543  1420  TAD I POINT
0009  0544  1100  TAD SUM1
0010  0545  3100  DCA SUM1
0011  0546  7004  RAL
0012  0547  1101  TAD SUM2
0013  0550  3101  DCA SUM2
0014  0551  2020  ISZ POINT
0015  0552  2022  ISZ COUNT
0016  0553  5343  JMP .-10
0017  0554  4031  JMS RESET
0018  0555  1100  TAD SUM1
0019  0556  3110  DCA X1
0020  0557  1101  TAD SUM2
0021  0560  3111  DCA X2
0022  0561  1100  TAD SUM1
0023  0562  3114  DCA Y1
0024  0563  1101  TAD SUM2
0025  0564  3115  DCA Y2
0026  0565  3112  DCA X3
0027  0566  3113  DCA X4
0028  0567  3116  DCA Y3
0029  0570  3117  DCA Y4
0030  0571  5734  JMP I GETX
0031              *0600
0032
0033  0600  7000  MPY, NOP
0034  0601  7300  CLA CLL
0035  0602  3104  DCA OR1
0036  0603  3105  DCA OR2
0037  0604  3106  DCA OR3
0038  0605  3107  DCA OR4
0039  0606  1114  TAD Y1
0040  0607  7041  CIA
0041  0610  3114  DCA Y1
0042  0611  7004  RAL
0043  0612  3152  DCA KEEP
0044  0613  1115  TAD Y2
0045  0614  7040  CMA
0046  0615  1152  TAD KEEP
0047  0616  3115  DCA Y2
0048  0617  7004  RAL
0049  0620  3152  DCA KEEP
0050  0621  1116  TAD Y3
0051  0622  7040  CMA
0052  0623  1152  TAD KEEP
0053  0624  3116  DCA Y3
```

Gets ΣX and puts into

X and Y registers for squaring

General multiplication routine for 48 bit unsigned numbers.

Clear MUL registers

Form 2's complement of multiplier

```
0054  0625  7004  RAL
0055  0626  3152  DCA KEEP
0056  0627  1117  TAD Y4
0057  0630  7040  CMA
0058  0631  1152  TAD KEEP
0059  0632  3117  DCA Y4
0060  0633  7300  DO, CLA CLL
0061  0634  1110  TAD X1
0062  0635  1104  TAD OR1
0063  0636  3104  DCA OR1
0064  0637  7004  RAL
0065  0640  1105  TAD OR2
0066  0641  3105  DCA OR2
0067  0642  7004  RAL
0068  0643  1106  TAD OR3
0069  0644  3106  DCA OR3
0070  0645  7004  RAL
0071  0646  1107  TAD OR4
0072  0647  3107  DCA OR4
0073  0650  7300  CLA CLL
0074  0651  1111  TAD X2
0075  0652  1105  TAD OR2
0076  0653  3105  DCA OR2
0077  0654  7004  RAL
0078  0655  1106  TAD OR3
0079  0656  3106  DCA OR3
0080  0657  7004  RAL
0081  0660  1107  TAD OR4
0082  0661  3107  DCA OR4
0083  0662  7300  CLA CLL
0084  0663  1112  TAD X3
0085  0664  1106  TAD OR3
0086  0665  3106  DCA OR3
0087  0666  7004  RAL
0088  0667  1107  TAD OR4
0089  0670  3107  DCA OR4
0090  0671  7300  CLA CLL
0091  0672  1113  TAD X4
0092  0673  1107  TAD OR4
0093  0674  3107  DCA OR4
0094  0675  7300  CLA CLL
0095  0676  7001  IAC
0096  0677  1114  TAD Y1
0097  0700  3114  DCA Y1
0098  0701  7004  RAL
0099  0702  1115  TAD Y2
0100  0703  3115  DCA Y2
0101  0704  7004  RAL
0102  0705  1116  TAD Y3
0103  0706  3116  DCA Y3
0104  0707  7004  RAL
0105  0710  1117  TAD Y4
0106  0711  3117  DCA Y4
0107  0712  1117  TAD Y4
```

Increment OR registers with value of mutliplicand until 2's complement of multiplier is = Ø.

The product of this is in OR1 ... OR3

```
0108  0713  7450  SNA
0109  0714  5600  JMP I MPY
0110  0715  5233  JMP DO
0111
0112  0716  7000  MINUS, NOP
0113  0717  3014  DCA SIGN
0114  0720  1114  TAD Y1
0115  0721  7041  CIA
0116  0722  1110  TAD X1
0117  0723  3104  DCA OR1
0118  0724  7004  RAL
0119  0725  3152  DCA KEEP
0120  0726  1115  TAD Y2
0121  0727  7040  CMA
0122  0730  1111  TAD X2
0123  0731  1152  TAD KEEP
0124  0732  3105  DCA OR2
0125  0733  7004  RAL
0126  0734  3152  DCA KEEP
0127  0735  1116  TAD Y3
0128  0736  7040  CMA
0129  0737  1112  TAD X3
0130  0740  1152  TAD KEEP
0131  0741  3106  DCA OR3
0132  0742  7004  RAL
0133  0743  3152  DCA KEEP
0134  0744  1117  TAD Y4
0135  0745  7040  CMA
0136  0746  1113  TAD X4
0137  0747  1152  TAD KEEP
0138  0750  3107  DCA OR4
0139  0751  7004  RAL
0140  0752  3014  DCA SIGN
0141  0753  5716  JMP I MINUS
0142
```

Form 2's complement of subtrahend and add it to minuend. Both numbers are unsigned and may be up to 48 bits.

SIGN= 1 if result is positive

```
0001                    *1000
0002  1000  7000  GETX2, NOP
0003  1001  4031  JMS RESET
0004  1002  3110  DCA X1
0005  1003  3111  DCA X2
0006  1004  3112  DCA X3
0007  1005  3113  DCA X4
0008  1006  3114  DCA Y1
0009  1007  3115  DCA Y2
0010  1010  3116  DCA Y3
0011  1011  3117  DCA Y4
0012  1012  3120  DCA SMX21
0013  1013  3121  DCA SMX22
0014  1014  3122  DCA SMX23
0015  1015  3123  DCA SMX24
0016
0017  1016  1420  PNTR, TAD I POINT
0018  1017  3110  DCA X1
0019  1020  1420  TAD I POINT
0020  1021  3114  DCA Y1
0021  1022  4536  JMS I MUL
0022  1023  7300  CLA CLL
0023  1024  1104  TAD OR1
0024  1025  1120  TAD SMX21
0025  1026  3120  DCA SMX21
0026  1027  7004  RAL
0027  1030  1121  TAD SMX22
0028  1031  3121  DCA SMX22
0029  1032  7004  RAL
0030  1033  1122  TAD SMX23
0031  1034  3122  DCA SMX23
0032  1035  7004  RAL
0033  1036  1123  TAD SMX24
0034  1037  3123  DCA SMX24
0035  1040  7300  CLA CLL
0036  1041  1105  TAD OR2
0037  1042  1121  TAD SMX22
0038  1043  3121  DCA SMX22
0039  1044  7004  RAL
0040  1045  1122  TAD SMX23
0041  1046  3122  DCA SMX23
0042  1047  7004  RAL
0043  1050  1123  TAD SMX24
0044  1051  3123  DCA SMX24
0045  1052  7300  CLA CLL
0046  1053  1106  TAD OR3
0047  1054  1122  TAD SMX23
0048  1055  3122  DCA SMX23
0049  1056  7004  RAL
0050  1057  1123  TAD SMX24
0051  1060  3123  DCA SMX24
0052  1061  7300  CLA CLL
0053  1062  1107  TAD OR4
```

Clear multiplier, multiplicand, and accumulator registers for the XY cross-products

Increment pointer, squaring the contents of the location indicated by it until all relevant points have been squared and summed in SMX21 ... SMX23

```
0054  1063  1123  TAD SMX24
0055  1064  3123  DCA SMX24
0056  1065  2020  ISZ POINT
0057  1066  2022  ISZ COUNT      Done with all points?
0058  1067  5216  JMP PNTR       No
0059  1070  4031  JMS RESET
0060  1071  1120  TAD SMX21      Yes, now put the sum of the
0061  1072  3110  DCA X1         squared scores into the multiplicand
0062  1073  1121  TAD SMX22
0063  1074  3111  DCA X2
0064  1075  1122  TAD SMX23
0065  1076  3112  DCA X3
0066  1077  1123  TAD SMX24
0067  1100  3113  DCA X4
0068  1101  1023  TAD RCOUNT    and put N into multiplier
0069  1102  7041  CIA
0070  1103  3114  DCA Y1
0071  1104  3115  DCA Y2
0072  1105  3116  DCA Y3
0073  1106  3117  DCA Y4
0074  1107  4536  JMS I MUL
0075  1110  7300  CLA CLL
0076  1111  1104  TAD OR1
0077  1112  3120  DCA SMX21
0078  1113  1105  TAD OR2        and get N ΣX² in the SMX2 registers
0079  1114  3121  DCA SMX22
0080  1115  1106  TAD OR3
0081  1116  3122  DCA SMX23
0082  1117  1107  TAD OR4
0083  1120  3123  DCA SMX24
0084  1121  5600  JMP I GETX2
0085
0086  1122  7000  DIVIS, NOP
0087  1123  7300  CLA CLL
0088  1124  1120  TAD SMX21      Divisor is formed by subtracting
0089  1125  3110  DCA X1         (ΣX)² from N ΣX²  and the
0090  1126  1121  TAD SMX22
0091  1127  3111  DCA X2         result is stored in DENOM registers
0092  1130  1122  TAD SMX23
0093  1131  3112  DCA X3
0094  1132  1123  TAD SMX24
0095  1133  3113  DCA X4
0096  1134  1100  TAD SUM1
0097  1135  3114  DCA Y1
0098  1136  1101  TAD SUM2
0099  1137  3115  DCA Y2
0100  1140  1102  TAD SUM3
0101  1141  3116  DCA Y3
0102  1142  1103  TAD SUM4
0103  1143  3117  DCA Y4
0104  1144  4541  JMS I SUBTR
0105
0106  1145  1104  TAD OR1
0107  1146  3124  DCA DENOM1
```

```
0108  1147  1105  TAD OR2
0109  1150  3125  DCA DENOM2
0110  1151  1106  TAD OR3
0111  1152  3126  DCA DENOM3
0112  1153  1107  TAD OR4
0113  1154  3127  DCA DENOM4
0114  1155  5722  JMP I DIVIS
0115
```

```
0001                    *1200
0002  1200  7402  RWTAPE, HLT
0003  1201  7300   CLA CLL
0004  1202  1600   TAD I RWTAPE
0005  1203  2200   ISZ RWTAPE
0006  1204  3325   DCA RWREGA
0007  1205  1600   TAD I RWTAPE
0008  1206  2200   ISZ RWTAPE
0009  1207  3327   DCA RWBLK
0010  1210  7040   CMA
0011  1211  1600   TAD I RWTAPE
0012  1212  2200   ISZ RWTAPE
0013  1213  3326   DCA RWCLOC
0014  1214  1323   TAD RWM12
0015  1215  3322   DCA RWTCNT
0016  1216  1333  RWBGN, TAD RWADBN
0017  1217  3731   DCA I RWADCA
0018  1220  1325   TAD RWREGA
0019  1221  0341   AND RW0077
0020  1222  7040   CMA
0021  1223  3330   DCA RWBCNT
0022
0023  1224  1325  TAD RWREGA
0024  1225  0334   AND RW7000
0025  1226  1335   TAD RW0610
0026  1227  6766   DTCA DTXA
0027  1230  4300  RWREV, JMS RWWAIT
0028  1231  5240   JMP RWFWD-4
0029  1232  1324   TAD RWBN
0030  1233  7040   CMA
0031  1234  1344   TAD M1
0032  1235  1327   TAD RWBLK
0033  1236  7710   SPA CLA
0034  1237  5230   JMP RWREV
0035
0036  1240  1325  TAD RWREGA
0037  1241  0334   AND RW7000
0038  1242  1336   TAD RW0210
0039  1243  6766   DTCA DTXA
0040  1244  4300  RWFWD, JMS RWWAIT
0041  1245  5216   JMP RWBGN
0042  1246  1324   TAD RWBN
0043  1247  7041   CIA
0044  1250  1327   TAD RWBLK
0045  1251  7450   SNA
0046  1252  5256   JMP .+4
0047  1253  7710   SPA CLA
0048  1254  5216   JMP RWBGN
0049  1255  5244   JMP RWFWD
0050
0051  1256  1325   TAD RWREGA
0052  1257  7112   CLL RTR
0053  1260  7010   RAR
```

Standard RWTAPE routine per Jim Crapuchettes. Modified to give 2-block turn-around for the benefit of middle-aged TU55s

```
0054  1261  0342   AND RW0070
0055  1262  1337   TAD RW0110
0056  1263  6764   DTXA
0057  1264  1326   TAD RWCLOC
0058  1265  3731   DCA I RWADCA
0059
0060  1266  2330  RWAGN, ISZ RWBCNT
0061  1267  5273   JMP .+4
0062  1270  1340   TAD RW0200
0063  1271  6764   DTXA
0064  1272  5600   JMP I RWTAPE
0065  1273  1343   TAD RWM200
0066  1274  3732   DCA I RWADWC
0067  1275  4300   JMS RWWAIT
0068  1276  5216   JMP RWBGN
0069  1277  5266   JMP RWAGN
0070
0071  1300  7402  RWWAIT, HLT
0072  1301  6764   DTXA
0073  1302  6771   DTSF
0074  1303  5302   JMP .-1
0075  1304  6772   DTRB
0076  1305  7700   SMA CLA
0077  1306  5320   JMP RWWOUT
0078  1307  2322   ISZ RWTCNT
0079  1310  5700   JMP I RWWAIT
0080  1311  6761   DTRA
0081  1312  0340   AND RW0200
0082  1313  7440   SZA
0083  1314  6764   DTXA
0084  1315  6772   DTRB
0085  1316  7402   HLT
0086  1317  5316   JMP .-1
0087  1320  2300   RWWOUT,ISZ RWWAIT
0088  1321  5700   JMP I RWWAIT
0089
0090
0091  1322  0000  RWTCNT,0000
0092  1323  7766  RWM12, -12
0093  1324  0000  RWBN,0000
0094  1325  0000  RWREGA,0000
0095  1326  0000  RWCLOC,0000
0096  1327  0000  RWBLK,0000
0097  1330  0000  RWBCNT,0000
0098  1331  7755  RWADCA,7755
0099  1332  7754  RWADWC,7754
0100  1333  1324  RWADBN,RWBN
0101  1334  7000  RW7000,7000
0102  1335  0610  RW0610,0610
0103  1336  0210  RW0210,0210
0104  1337  0110  RW0110,0110
0105  1340  0200  RW0200,0200
0106  1341  0077  RW0077,0077
0107  1342  0070  RW0070,0070
```

```
AUTOCORRELATION ROUTINE     MAY,1973      T. GLATTKE
RECORD 6


0108   1343   7600   RWM200,-20#
0109   1344   7777   M1, 7777
0110
0111
```

```
0001                    *1400
0002  1400  7000  XYPROD, NOP
0003  1401  7300  CLA CLL
0004  1402  3130  DCA XY1
0005  1403  3131  DCA XY2
0006  1404  3132  DCA XY3
0007  1405  3133  DCA XY4
0008  1406  4031  JMS RESET
0009
0010  1407  1020  DOXY,TAD POINT      Setup delay
0011  1410  1030  TAD DELAY
0012  1411  3026  DCA DPOINT
0013  1412  1026  TAD DPOINT
0014  1413  1027  TAD CHECK
0015  1414  7510  SPA
0016  1415  5222  JMP .+5
0017  1416  7300  CLA CLL
0018  1417  1026  TAD DPOINT
0019  1420  1023  TAD RCOUNT
0020  1421  3026  DCA DPOINT
0021  1422  7300  CLA CLL
0022  1423  1420  TAD I POINT        Put contents of location indicated
0023  1424  3110  DCA X1             by "point" into multiplicand
0024  1425  3111  DCA X2
0025  1426  3112  DCA X3
0026  1427  3113  DCA X4
0027  1430  1426  TAD I DPOINT
0028  1431  3114  DCA Y1             And the "delay" data into the
0029  1432  3115  DCA Y2             multiplier
0030  1433  3116  DCA Y3
0031  1434  3117  DCA Y4
0032
0033  1435  4536  JMS I MUL
0034  1436  7300  CLA CLL
0035  1437  1104  TAD OR1
0036  1440  1130  TAD XY1
0037  1441  3130  DCA XY1            And accumulate the XY products
0038  1442  7004  RAL
0039  1443  1131  TAD XY2            in the XY registers
0040  1444  3131  DCA XY2
0041  1445  7004  RAL
0042  1446  1132  TAD XY3
0043  1447  3132  DCA XY3
0044  1450  7004  RAL
0045  1451  1133  TAD XY4
0046  1452  3133  DCA XY4
0047  1453  7300  CLA CLL
0048  1454  1105  TAD OR2
0049  1455  1131  TAD XY2
0050  1456  3131  DCA XY2
0051  1457  7004  RAL
0052  1460  1132  TAD XY3
0053  1461  3132  DCA XY3
```

```
0054  1462  7004  RAL
0055  1463  1133  TAD XY4
0056  1464  3133  DCA XY4
0057  1465  7300  CLA CLL
0058  1466  1106  TAD OR3
0059  1467  1132  TAD XY3
0060  1470  3132  DCA XY3
0061  1471  7004  RAL
0062  1472  1133  TAD XY4
0063  1473  3133  DCA XY4
0064  1474  7300  CLA CLL
0065  1475  1107  TAD OR4
0066  1476  1133  TAD XY4
0067  1477  3133  DCA XY4
0068  1500  2020  ISZ POINT
0069  1501  2022  ISZ COUNT
0070  1502  5207  JMP DOXY
0071
0072  1503  7300  CLA CLL
0073  1504  1130  TAD XY1
0074  1505  3110  DCA X1
0075  1506  1131  TAD XY2
0076  1507  3111  DCA X2
0077  1510  1132  TAD XY3
0078  1511  3112  DCA X3
0079  1512  1133  TAD XY4
0080  1513  3113  DCA X4
0081  1514  1023  TAD RCOUNT
0082  1515  7041  CIA
0083  1516  3114  DCA Y1
0084  1517  3115  DCA Y2
0085  1520  3116  DCA Y3
0086  1521  3117  DCA Y4
0087  1522  4536  JMS I MUL
0088  1523  1104  TAD OR1
0089  1524  3130  DCA XY1
0090  1525  1105  TAD OR2
0091  1526  3131  DCA XY2
0092  1527  1106  TAD OR3
0093  1530  3132  DCA XY3
0094  1531  1107  TAD OR4
0095  1532  3133  DCA XY4
0096  1533  5600  JMP I XYPROD
0097              *1600
0098  1600  7000  DIVID, NOP
0099  1601  7300  CLA CLL
0100  1602  1130  TAD XY1
0101  1603  3110  DCA X1
0102  1604  1131  TAD XY2
0103  1605  3111  DCA X2
0104  1606  1132  TAD XY3
0105  1607  3112  DCA X3
0106  1610  1133  TAD XY4
0107  1611  3113  DCA X4
```

Done?

Then obtain $N\Sigma XY$ by putting the ΣXY into multiplicand and N into multiplier

The dividend is formed as in the case of the divisor, but the SIGN is noted.

```
0108  1612  1100  TAD SUM1
0109  1613  3114  DCA Y1
0110  1614  1101  TAD SUM2
0111  1615  3115  DCA Y2
0112  1616  1102  TAD SUM3
0113  1617  3116  DCA Y3
0114  1620  1103  TAD SUM4
0115  1621  3117  DCA Y4
0116  1622  4541  JMS I SUBTR
0117
0118  1623  1014  TAD SIGN
0119  1624  7650  SNA CLA
0120  1625  5246  JMP UNNML
0121  1626  7300  CLA CLL
0122  1627  3015  DCA NEGATE
0123  1630  1104  TAD OR1
0124  1631  3110  DCA X1
0125  1632  1105  TAD OR2
0126  1633  3111  DCA X2
0127  1634  1106  TAD OR3
0128  1635  3112  DCA X3
0129  1636  1107  TAD OR4
0130  1637  3113  DCA X4
0131  1640  1016  TAD K1000
0132  1641  3114  DCA Y1
0133  1642  3115  DCA Y2
0134  1643  3116  DCA Y3
0135  1644  3117  DCA Y4
0136
0137  1645  5303  JMP XDO
0138
0139  1646  7300  UNNML, CLA CLL
0140  1647  7001  IAC
0141  1650  3015  DCA NEGATE
0142  1651  1104  TAD OR1
0143  1652  7041  CIA
0144  1653  3110  DCA X1
0145  1654  7004  RAL
0146  1655  3305  DCA LINC
0147  1656  1105  TAD OR2
0148  1657  7040  CMA
0149  1660  1305  TAD LINC
0150  1661  3111  DCA X2
0151  1662  7004  RAL
0152  1663  3305  DCA LINC
0153  1664  1106  TAD OR3
0154  1665  7040  CMA
0155  1666  1305  TAD LINC
0156  1667  3112  DCA X3
0157  1670  7004  RAL
0158  1671  3305  DCA LINC
0159  1672  1107  TAD OR4
0160  1673  7040  CMA
0161  1674  1305  TAD LINC
```

If sign=1, the resulting r will be positive (or 0). And the denominator is simply multiplied by 1000_8 to provide for suitable display of the results.

If the sign is Ø, the result will be (-) and the correlation is obtained by multiplying the 2s comp of the dividend by 1000_8 ...as above... and keeping track of the (-) indicator.

```
0162  1675  3113  DCA X4
0163  1676  1016  TAD K1000
0164  1677  3114  DCA Y1
0165  1700  3115  DCA Y2
0166  1701  3116  DCA Y3
0167  1702  3117  DCA Y4
0168  1703  4536  XDO, JMS I MUL
0169  1704  5600  JMP I DIVID
0170  1705  0000  LINC, 0000
```

```
0001  BEGBLK  0010
0002  BLKS    0011
0003  CHECK   0027
0004  CORCNT  0013
0005  CORE    0046
0006  CORR    0024
0007  COUNT   0022
0008  CROSPD  0263
0009  DELAY   0030
0010  DENOM   0140
0011  DENOM1  0124
0012  DENOM2  0125
0013  DENOM3  0126
0014  DENOM4  0127
0015  DISPLY  0400
0016  DIVID   1600
0017  DIVIS   1122
0018  DO      0633
0019  DOCO    0270
0020  DOXY    1407
0021  DPOINT  0026
0022  DXNT    0533
0023  GET     0472
0024  GETX    0534
0025  GETX2   1000
0026  HALF    0070
0027  INB     0477
0028  INCR    0146
0029  KEEP    0152
0030  KPOINT  0150
0031  K1000   0016
0032  K2      0162
0033  K4      0532
0034  K7      0161
0035  K777    0017
0036  LIMIT   0061
0037  LINC    1705
0038  MINUS   0716
0039  MPY     0600
0040  MUL     0136
0041  M1      1344
0042  NEGATE  0015
0043  NEXT    0351
0044  NUMER   0143
0045  OR1     0104
0046  OR2     0105
0047  OR3     0106
0048  OR4     0107
0049  OUT     0454
0050  PNTR    1016
0051  POINT   0020
0052  RCORR   0025
0053  RCOUNT  0023
```

0054	READ	0134
0055	RESET	0031
0056	RESETC	0517
0057	RESETD	0507
0058	RPOINT	0021
0059	RW	0147
0060	RWADBN	1333
0061	RWADCA	1331
0062	RWADWC	1332
0063	RWAGN	1266
0064	RWBCNT	1330
0065	RWBGN	1216
0066	RWBLK	1327
0067	RWBN	1324
0068	RWCLOC	1326
0069	RWFWD	1244
0070	RWM12	1323
0071	RWM200	1343
0072	RWREGA	1325
0073	RWREV	1230
0074	RWTAPE	1200
0075	RWTCNT	1322
0076	RWWAIT	1300
0077	RWWOUT	1320
0078	RW0070	1342
0079	RW0077	1341
0080	RW0110	1337
0081	RW0200	1340
0082	RW0210	1336
0083	RW0610	1335
0084	RW7000	1334
0085	SETCOR	0041
0086	SIGN	0014
0087	SMX21	0120
0088	SMX22	0121
0089	SMX23	0122
0090	SMX24	0123
0091	START	0200
0092	SUBTR	0141
0093	SUMX	0135
0094	SUMX2	0137
0095	SUM1	0100
0096	SUM2	0101
0097	SUM3	0102
0098	SUM4	0103
0099	TALLY	0144
0100	TFLAG	0145
0101	UNNML	1646
0102	WBLK	0012
0103	XAXIS	0151
0104	XDO	1703
0105	XPROD	0142
0106	XSET	0153
0107	XSTART	0470

```
0108  XYPROD  1400
0109  XY1     0130
0110  XY2     0131
0111  XY3     0132
0112  XY4     0133
0113  X1      0110
0114  X2      0111
0115  X3      0112
0116  X4      0113
0117  Y1      0114
0118  Y2      0115
0119  Y3      0116
0120  Y4      0117
```