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DECUS NO.	8-304
TITLE	PSEUDO-NOISE (P-N) SEQUENCE TEST
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SOURCE LANGUAGE	PAL

PSEUDO-NOISE (P-N) SEQUENCE TEST

DECUS Program Library Write-up DECUS No. 8-304

ABSTRACT

This program can be used to determine the statistical characteristics of a pseudo-random sequence generator. The probability density function can be studied with the aid of an amplitude histogram, and measures of the "randomness" can be determined with correlation diagrams, sample function displays, and scattergrams. All diagrams are displayed on the CRT.

REQUIREMENTS

Storage

Program: 0-1,16-171,200-356,400-572,600-713

Date: 2000-5777*

Axis Points: 1000-1777*

*Data and Axis Points are stored as (x,y) co-ordinates, $(x_0y_0x_1y_1\ldots..)$

Equipment

PDP-8 with EAE, display, A/D converter, and external interrupt. The 6424 instruction seen in this program resets the clock interrrupt at the Carleton installation. It is used to time sampling of the pseudo-random sequences and should be replaced by the appropriate instruction or NOP when implemented at a different installation.

USAGE

Calling Sequence

The program is called by setting the switch register to 0200 and pressing "load address." The switches are reset for the desired test configuration and "start" is pressed.

Switch Settings

(I) The type of test to be used is determined by switches 1 and 2.

S_1	S_2	
0	0	Amplitude Histogram
0	1	Correlation Diagram
1	0	Scattergram
1	1	Sample Function Display

(II) The input mode is determined by switch 0.

S_0	
0	Software*
1	A/D converter (channel 0)

*Unless changes are made, the program will extract pseudo-random numbers from its own reference software generator, RAND, stored in locations 0136-0156. It is a mixed congruential generator whose sequence is defined by the following algorithm.

$$x_{i+1} = x_i(2^6+3) + 3 \quad \text{modulo } 2^{12}$$

where $x_0=1$.

If a different software generator is required, it must be read into unused locations in memory and a JMS to its starting address inserted in location 0074.

(III) When the correlation diagram is used, the shift (minus one) between the samples plotted as co-ordinate pairs is determined by switches 3-11. Hence, the maximum shift is 512.

(IV) A change in the test being run can be effected by resetting the switch register for the new test, and depressing any teletype key.

RESTRICTIONS

Allowable Range

This program is intended for testing 10 bit pseudo-random numbers, considered to be in the low order 10 bits of the accumulator.

DESCRIPTION

Discussion

(I) Amplitude Histogram - This is a free running accumulation of the number of occurrences of a particular number in a finite record of a pseudo-random sequence. The maximum accumulation is determined by the rise increment, IN. Each time a particular number occurs, its accumulation counter is incremented by IN. With IN set at $10_8=8_{10}$, the maximum accumulation is $177_8 = 128_{10}$. A visual indication of the first order probability density function of the sequence under is given by this display.

For pseudo-random number generators with uniform distributions, the mean accumulation and variance (on the mean accumulation) may be determined as follows:

Stop the histogram test when a suitable display has been obtained (an approximate mean accumulation more than half way up the vertical axis). The mean accumulation will appear in the ACC, as defined by:

$$\bar{y}_n = 1/1024 \sum_{i=1}^{1024} y_i$$

where y_i is the value of the i^{th} accumulation counter. This must be normalized by N, the number of samples, to be compared with the theoretical estimate (assuming N independent trials of the generator).

$$\bar{y}_t = 1/1024 \qquad \text{(for 1024 quantization levels)}$$

Press "continue." The variance on the mean accumulation will appear, high order 12 bits in the ACC, low order 12 bits in the MQ:

$$\sigma^2 = \sum_{i=1}^{1024} (y_i - \bar{y}_n)^2$$

This must be divided by $(1024 \cdot N^2)$ for proper normalization. It may then be compared with the theoretical estimate of the variance on the mean accumulation (again assuming N independent trials).

$$\sigma^2 = 1/(1024 \cdot N)$$

Press "continue." The number of samples taken for the histogram will appear, high order 12 bits in the ACC, low order 12 bits in the MQ.

(II) Correlation Diagram - A visual indication of the correlation between successive samples may be obtained from the correlation diagram. It is a display of (1024+(s+1)) samples. Co-ordinates are formed from (r_i, r_{i+s+1}) where the r_i are samples of the pseudo-random sequence.

(III) Scattergram – A measure of the "randomness" of the sequence under test may be obtained from the scattergram or successive pairs diagram. Co-ordinates are formed by plotting successive pairs of samples of the sequence as (x,y) co-ordinates as follows:

$$(r_0, r_1),\ (r_2, r_3),\ (r_4, r_5) \ldots\ldots$$

This display is free-running and takes in 1024 such pairs before overwriting the oldest pairs. Further details of the use of this diagram are given by Chambers (1).

(IV) Sample Function Display - Further indications of the structure or patterns in the sequence are provided by the display of a finite record of the output of the generator under test. In this display, (i, r_i) is plotted as an (x,y) co-ordinate, where r_i is a sample of the pseudo-random sequence, and i is the sample index. The display is free-running and takes in 1024 samples before overwriting the oldest samples.

EXECUTION TIME

The histogram test has an approximate maximum frequency of 6 khz. The other tests have approximate maximum interrupt frequencies of 4 khz.

These frequencies are quoted for sampling from an A/D converter with a 50 usec. conversion time.

REFERENCES

1. R. P. Chambers, "Random-number Generation On Digital Computers," IEEE Spectrum, February 1967, pp. 48-56.

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                /PSEUDO-RANDOM SEQUENCE GENERATOR
                /AMPLITUDE HISTOGRAM, CORRELATION
                /DIAGRAM (SCATTERGRAM), AND SAMPLE
                /FUNCTION OBSERVATION.
                        *ØØØØ
ØØØØ    ØØØØ            ØØØØ
ØØØ1    51ØØ            JMP SER  /  JUMP TO INTERRUPT SERVICE
                        *ØØ16
ØØ16    ØØØØ    MEM,Ø
ØØ17    ØØØØ    MEMI,Ø
ØØ2Ø    ØØØØ    NØ,Ø
ØØ21    ØØØØ    NØ1,Ø
ØØ22    ØØØØ    XMIN,Ø
ØØ23    ØØØØ    MTEMP,Ø
ØØ24    ØØØØ    X,Ø
ØØ25    ØØØØ    Y,Ø
ØØ26    Ø4ØØ    THOU,Ø4ØØ / NUMBER OF AXIS POINTS
ØØ27    76ØØ    CNT, 76ØØ / NO. OF POINTS ON 1 AXIS
ØØ3Ø    ØØØØ    CNT1,Ø
ØØ31    ØØ1Ø    INC,ØØ1Ø / INCREMENT BETWEEN POINTS
ØØ32    ØØØØ    AØ,Ø / ORIGIN
ØØ33    ØØØØ    BØ,Ø / SETTINGS
ØØ34    ØØØØ    AC,Ø / ACC-TEMPORARY STORAGE
ØØ35    ØØØØ    PL1,ØØØØ
ØØ36    Ø2ØØ    PL2,Ø2ØØ
ØØ37    Ø777    MØ,Ø777 / INITIAL AXIS ADDRESS MINUS ONE
ØØ4Ø    2ØØØ    XØ,2ØØØ / INITIAL X ADDRESS
ØØ41    2ØØ1    YØ,2ØØ1 / INITIAL Y ADDRESS
ØØ42    ØØØØ    XLOC,Ø
ØØ43    ØØØØ    YLOC,Ø
ØØ44    ØØØØ    CNTR,Ø
ØØ45    2ØØØ    NRAND,2ØØØ
ØØ46    ØØØØ    IR,Ø / SAMPLE INDEX
ØØ47    ØØØØ    S,Ø / SEPARATION MINUS ONE
ØØ5Ø    ØØØØ    T1,Ø
ØØ51    1777    MASK,1777
ØØ52    Ø777    MASKS,Ø777
ØØ53    Ø177    MASKV,Ø177
ØØ54    ØØØ3    MASKH,ØØØ3
ØØ55    Ø535    EXEC,AXIS
ØØ56    1ØØØ    CORR,1ØØØ / Y AXIS SHIFT ON HISTOGRAM
ØØ57    Ø336    HT,HSTINT
ØØ6Ø    Ø4ØØ    SC1,SCAT1 / INTERRUPT SERVICE POINTERS
ØØ61    Ø417    SC2,SCAT2
ØØ62    Ø442    SC3,SCAT3
ØØ63    Ø456    SC4,WAIT
ØØ64    Ø46Ø    SCP,SEQ
ØØ65    Ø5Ø7    SA1,SAMP1
ØØ66    7777    SOFT,7777
ØØ67    ØØØØ    HIGH,ØØØØ
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ØØ7Ø  ØØØØ  LOW,ØØØØ
ØØ71  ØØØØ  HOR,ØØØØ
ØØ72  ØØØØ  LOR,ØØØØ
ØØ73  4157  CHGE, JMS A2D / SOFTWARE,A/D CONVERTER
ØØ74  4136  SET, JMS RAND / SAMPLING LINKS
ØØ75  ØØØØ  CNIX,Ø
ØØ76  ØØØØ  NPT1,Ø / SAMPLES COUNTER, HIGH ORDER
ØØ77  ØØØØ  NPT2,Ø / LOW ORDER
Ø1ØØ  3Ø34  SER,    DCA AC / INTERRUPT SERVICE LINK
Ø1Ø1  6424          6424 / RESET CLOCK
Ø1Ø2  6Ø31          6Ø31 / KEYBOARD INTERRUPT?
Ø1Ø3  741Ø          SKP
Ø1Ø4  5436          JMP I PL2 / YES, SET UP NEW TEST
Ø1Ø5  4435          JMS I PL1 / NO, SERVICE INTERRUPT
Ø1Ø6  73ØØ          CLA CLL
Ø1Ø7  1Ø34          TAD AC / RESTORE ACC
Ø11Ø  6ØØ1          ION / ENABLE INTERRUPT
Ø111  54ØØ          JMP I ØØØØ / CONTINUE DISPLAY
Ø112  6Ø77  TRACE,  6Ø77 / DISPLAY ROUTINE-SET INTENSITY
Ø113  6424          6424 / RESET CLOCK
Ø114  6ØØ1          ION / ENABLE INTERRUPT
Ø115  73ØØ  START,  CLA CLL
Ø116  1Ø16          TAD MEM / PUT INITIAL ADDRESS MINUS
Ø117  3Ø23          DCA MTEMP / ONE IN TEMP STORE
Ø120  1Ø2Ø          TAD NØ
Ø121  7Ø41          CIA / SET POINTS COUNTER
Ø122  3Ø21          DCA NØ1
Ø123  1416  C,      TAD I MEM
Ø124  6Ø52          6Ø52
Ø125  73ØØ          CLA CLL
Ø126  1416          TAD I MEM / DISPLAY CO-ORDINATE
Ø127  6Ø66          6Ø66
Ø13Ø  73ØØ          CLA CLL
Ø131  2Ø21          ISZ NØ1 / FINISHED?
Ø132  5123          JMP C / NO, CONTINUE
Ø133  1Ø23          TAD MTEMP / YES, REINITIALIZE
Ø134  3Ø16          DCA MEM
Ø135  5115          JMP START / RESTART DISPLAY
Ø136  ØØØØ  RAND,   Ø / MIXED CONGRUENTIAL
Ø137  7621          CLA MQL / PSEUDO-RANDOM NUMBER
Ø14Ø  1155          TAD RN / GENERATOR
Ø141  7413          SHL / R(I+1)=R(I)*(2 ↑ 6+3)+3
Ø142  ØØØ5          ØØØ5 / MODULO 2↑12
Ø143  1155          TAD RN
Ø144  1155          TAD RN
Ø145  1155          TAD RN
Ø146  1156          TAD THREE
Ø147  3155          DCA RN
Ø15Ø  1155          TAD RN
Ø151  7Ø12          RTR
Ø152  ØØ51          AND MASK / TAKE HIGH ORDER 1Ø BITS
Ø153  5536          JMP I RAND / FOR DISPLAY TESTS
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0154  0001  RN0,0001
0155  0000  RN,0000
0156  0003  THREE,0003
0157  0000  A2D,     0 / SAMPLE SEQUENCE VIA A/D CONVERTER
0160  7300          CLA CLL
0161  6542          ADSC / SET TO CHANNEL 0
0162  6532          ADCV
0163  6531          ADSF
0164  5163          JMP .-1  / SAMPLE SEQUENCE
0165  6534          ADRB
0166  5557          JMP I A2D / RETURN
0167  0000  FETCH,  0 / FETCH A SAMPLE
0170  4136  G1,     JMS RAND
0171  5567          JMP I FETCH / RETURN
                    *0200 / START OF TESTS
0200  6032          6032 / CLEAR KEYBOARD FLAG
0201  7300          CLA CLL
0202  1154          TAD RN0 / INITIALIZE SOFTWARE
0203  3155          DCA RN / GENERATOR
0204  1074          TAD SET
0205  3170          DCA G1 / SET SOFTWARE-A/D CONVERTER CHOICE
0206  1037          TAD MQ / SET INITIAL DATA STORAGE ADDRESS
0207  3016          DCA MEM
0210  1045          TAD NRAND / SET POINTS COUNTER
0211  1026          TAD THOU
0212  3020          DCA N0
0213  7604          LAS
0214  7104          CLL RAL
0215  7620          SNL CLA / READ BIT 0;  CHOOSE INPUT MODE
0216  5221          JMP TSTRD / SOFTWARE REQUIRED (0)
0217  1073          TAD CHGE / A/D CONVERTER REQUIRED (1)
0220  3170          DCA G1
0221  7604  TSTRD,  LAS
0222  7006          RTL
0223  7006          RTL
0224  0054          AND MASKH / READ BITS 1, 2;  CHOOSE TEST
0225  7450          SNA
0226  5236          JMP HIS / HISTOGRAM REQUIRED (00)
0227  1066          TAD SOFT
0230  7450          SNA
0231  5244          JMP SCA1 / SCATTERGRAM REQUIRED (01)
0232  1066          TAD SOFT
0233  7650          SNA CLA
0234  5257          JMP SCAP / SUCCESSIVE PAIRS PLOT (02)
0235  5265          JMP SCA2 / SAMPLE FUNCTION REQUIRED (03)
0236  1056  HIS,    TAD CORR / HISTOGRAM PRELIMINARY
0237  3022          DCA XMIN / CORRECT Y AXIS MARKER
0240  3024          DCA X / CLEAR AXIS COUNTER
0241  1057          TAD HT / SET UP HISTOGRAM INTERRUPT
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Ø242  3Ø35          DCA PL1 / SERVICE LINK
Ø243  5316          JMP HISTGM / PROCEED WITH HISTOGRAM
Ø244  4272  SCA1,   JMS CLEAR / SCATTERGRAM PRELIMINARY
Ø245  1Ø6Ø          TAD SC1 / SET UP SCATTERGRAM INTERRUPT
Ø246  3Ø35          DCA PL1 / SERVICE LINK
Ø247  76Ø4          LAS / DETERMINATION SEPARATION (S)
Ø25Ø  ØØ52          AND MASKS / FROM BITS 3-11
Ø251  7ØØ1          IAC
Ø252  3Ø47          DCA S
Ø253  1Ø47          TAD S
Ø254  7Ø41          CIA / SET HISTORY COUNTER
Ø255  3Ø44          DCA CNTR
Ø256  5455          JMP I EXEC / JUMP TO AXIS GENERATION
Ø257  4272  SCAP,   JMS CLEAR / SUCCESSIVE PAIRS PLOT
Ø26Ø  1Ø64          TAD SCP / PRELIMINARY
Ø261  3Ø35          DCA PL1
Ø262  724Ø          CLA CMA / SET XY COUNTER
Ø263  3Ø75          DCA CNTX
Ø264  5455          JMP I EXEC / JUMP TO AXIS GENERATION
Ø265  4272  SCA2,   JMS CLEAR / SAMPLE FUNCTION PRELIMINARY
Ø266  1Ø65          TAD SA1 / SET UP SAMPLE FUNCTION INTERRUPT
Ø267  3Ø35          DCA PL1 / SERVICE LINK
Ø27Ø  3Ø46          DCA IR / CLEAR SAMPLE INDEX
Ø271  5455          JMP I EXEC / JUMP TO AXIS GENERATION
Ø272  ØØØØ  CLEAR,  Ø / INITIALIZATION
Ø273  1Ø45          TAD NRAND
Ø274  71Ø4          CLL RAL
Ø275  7Ø41          CIA
Ø276  3Ø21          DCA NØ1
Ø277  1Ø4Ø          TAD XØ
Ø3ØØ  3Ø42          DCA XLOC
Ø3Ø1  3442          DCA I XLOC / CLEAR DATA REGISTERS
Ø3Ø2  2Ø42          ISZ XLOC
Ø3Ø3  2Ø21          ISZ NØ1
Ø3Ø4  53Ø1          JMP .-3
Ø3Ø5  1Ø4Ø          TAD XØ / CLEAR X ADDRESS
Ø3Ø6  3Ø42          DCA XLOC
Ø3Ø7  1Ø41          TAD YØ
Ø31Ø  3Ø43          DCA YLOC / CLEAR Y ADDRESS
Ø311  3Ø22          DCA XMIN / CLEAR Y AXIS MARKER
Ø312  1Ø45          TAD NRAND
Ø313  7Ø41          CIA / SET POINTS COUNTER
Ø314  3Ø5Ø          DCA T1
Ø315  5672          JMP I CLEAR / RETURN
Ø316  1Ø45  HISTGM, TAD NRAND / HISTOGRAM SETUP
Ø317  7Ø41          CIA / SET POINTS COUNTER (1Ø24)
Ø32Ø  3Ø21          DCA NØ1
Ø321  1Ø4Ø          TAD XØ
Ø322  3Ø42          DCA XLOC / SET REGISTERS
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Ø323  1Ø24  CLR,     TAD X
Ø324  3442           DCA I XLOC
Ø325  2Ø42           ISZ XLOC
Ø326  3442           DCA I XLOC
Ø327  2Ø42           ISZ XLOC
Ø33Ø  2Ø24           ISZ X
Ø331  2Ø21           ISZ NØ1
Ø332  5323           JMP CLR
Ø333  3Ø76           DCA NPT1 / CLEAR SAMPLES COUNTER
Ø334  3Ø77           DCA NPT2
Ø335  5455           JMP I EXEC / JUMP TO AXIS GENERATION
Ø336  ØØØØ  HSTINT,  Ø / HISTOGRAM INTERRUPT SERVICE
Ø337  73ØØ           CLA CLL
Ø34Ø  1Ø77           TAD NPT2
Ø341  7ØØ1           IAC / INCREMENT SAMPLES COUNTER (24 BIT)
Ø342  3Ø77           DCA NPT2
Ø343  7ØØ4           RAL
Ø344  1Ø76           TAD NPT1
Ø345  3Ø76           DCA NPT1
Ø346  4167           JMS FETCH / FETCH SAMPLE
Ø347  71Ø4           CLL RAL / TIMES TWO FOR PROPER STORAGE
Ø35Ø  1Ø41           TAD YØ
Ø351  3Ø43           DCA YLOC
Ø352  1443           TAD I YLOC / UPDATE DISPLAY
Ø353  1356           TAD IN
Ø354  3443           DCA I YLOC
Ø355  5736           JMP I HSTINT / RETURN
Ø356  ØØ1Ø  IN,ØØ1Ø  / RISE INCREMENT OF HISTOGRAM
                     *Ø4ØØ
Ø4ØØ  ØØØØ  SCAT1,   Ø / SCATTERGRAM SERVICE 1
Ø4Ø1  2Ø44           ISZ CNTR
Ø4Ø2  741Ø           SKP
Ø4Ø3  5211           JMP FIN / TAKE IN S SAMPLES AND STORE
Ø4Ø4  4167  F1,      JMS FETCH / IN X ARRAY
Ø4Ø5  3442           DCA I XLOC
Ø4Ø6  2Ø42           ISZ XLOC
Ø4Ø7  2Ø42           ISZ XLOC
Ø41Ø  56ØØ           JMP I SCAT1
Ø411  1Ø61  FIN,     TAD SC2 / FINISHED. CHANGE INTERRUPT
Ø412  3Ø35           DCA PL1 / LINK
Ø413  1Ø5Ø           TAD T1
Ø414  1Ø47           TAD S
Ø415  3Ø5Ø           DCA T1
Ø416  52Ø4           JMP F1
Ø417  ØØØØ  SCAT2,   Ø / SCATTERGRAM SERVICE 2
Ø42Ø  2Ø5Ø           ISZ T1
Ø421  741Ø           SKP
Ø422  5234           JMP FIN2 / TAKE IN (NRAND-S)
Ø423  4167  F2,      JMP FETCH / SAMPLES AND STORE
Ø424  3443           DCA I YLOC / IN X AND Y ARRAYS
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Ø425  1443          TAD I YLOC
Ø426  3442          DCA I XLOC
Ø427  2Ø42          ISZ XLOC
Ø43Ø  2Ø42          ISZ XLOC
Ø431  2Ø43          ISZ YLOC
Ø432  2Ø43          ISZ YLOC
Ø433  5617          JMP I SCAT2
Ø434  1Ø62  FIN2,   TAD SC3 / FINISHED.  CHANGE INTERRUPT
Ø435  3Ø35          DCA PL1 / LINK
Ø436  1Ø47          TAD S
Ø437  7Ø41          CIA
Ø44Ø  3Ø44          DCA CNTR
Ø441  5223          JMP F2
Ø442  ØØØØ  SCAT3,  Ø / SCATTERGRAM SERVICE 3
Ø443  2Ø44          ISZ CNTR
Ø444  741Ø          SKP
Ø445  5253          JMP FIN3 / TAKE IN S SAMPLES AND
Ø446  4167  F3,     JMS FETCH / STORE IN Y ARRAY
Ø447  3443          DCA I YLOC
Ø45Ø  2Ø43          ISZ YLOC
Ø451  2Ø43          ISZ YLOC
Ø452  5642          JMP I SCAT3
Ø453  1Ø63  FIN3,   TAD SC4 / FINISHED.  CHANGE INTERRUPT
Ø454  3Ø35          DCA PL1 / LINK
Ø455  5246          JMP F3
Ø456  ØØØØ  WAIT,   Ø / INTERRUPT WAIT LOOP
Ø457  5656          JMP I WAIT
Ø46Ø  ØØØØ  SEQ,    Ø / SUCCESSIVE PAIRS SERVICE
Ø461  4167          JMS FETCH / FETCH SAMPLE
Ø462  2Ø75          ISZ CNTX / X OR Y
Ø463  5272          JMP YST
Ø464  3442          DCA I XLOC / STORE X
Ø465  2Ø42          ISZ XLOC
Ø466  2Ø42          ISZ XLOC
Ø467  7344          CLA CLL CMA RAL / RESET COUNTER
Ø47Ø  3Ø75          DCA CNTX
Ø471  566Ø          JMP I SEQ / RETURN
Ø472  3443  YST,    DCA I YLOC / STORE Y
Ø473  2Ø43          ISZ YLOC
Ø474  2Ø43          ISZ YLOC
Ø475  2Ø5Ø          ISZ T1 / ADDRESS RESET NEEDED?
Ø476  566Ø          JMP I SEQ / NO, RETURN
Ø477  1Ø4Ø          TAD XØ / YES
Ø5ØØ  3Ø42          DCA XLOC
Ø5Ø1  1Ø41          TAD YØ
Ø5Ø2  3Ø43          DCA YLOC
Ø5Ø3  1Ø45          TAD NRAND
Ø5Ø4  7Ø41          CIA
Ø5Ø5  3Ø5Ø          DCA T1
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Ø5Ø6  566Ø          JMP I SEQ / RETURN
Ø5Ø7  ØØØØ  SAMP1,  Ø / SAMPLE FUNCTION INTERRUPT SERVICE
Ø51Ø  73ØØ          CLA CLL
Ø511  2Ø5Ø          ISZ T1
Ø512  5323          JMP GG3
Ø513  1Ø45          TAD NRAND / RESET ADDRESSES
Ø514  7Ø41          CIA
Ø515  3Ø5Ø          DCA T1
Ø516  1Ø4Ø          TAD XØ
Ø517  3Ø42          DCA XLOC
Ø52Ø  3Ø46          DCA IR
Ø521  1Ø41          TAD YØ
Ø522  3Ø43          DCA YLOC
Ø523  4167  GG3,    JMS FETCH / FETCH SAMPLE
Ø524  3443          DCA I YLOC
Ø525  2Ø43          ISZ YLOC / UPDATE DISPLAY
Ø526  2Ø43          ISZ YLOC
Ø527  1Ø46          TAD IR
Ø53Ø  3442          DCA I XLOC
Ø531  2Ø42          ISZ XLOC
Ø532  2Ø42          ISZ XLOC
Ø533  2Ø46          ISZ IR
Ø534  57Ø7          JMP I SAMP1 / RETURN
Ø535  1Ø16  AXIS,   TAD MEM / AXIS GENERATION
Ø536  3Ø23          DCA MTEMP
Ø537  4365          JMS RSET / INITIALIZE
Ø54Ø  1Ø22  A,      TAD XMIN
Ø541  3416          DCA I MEM
Ø542  1Ø25          TAD Y / STORE VERTICAL AXIS POINTS
Ø543  3416          DCA I MEM
Ø544  1Ø25          TAD Y
Ø545  1Ø31          TAD INC / INCREMENT COUNTER
Ø546  3Ø25          DCA Y
Ø547  2Ø3Ø          ISZ CNT1
Ø55Ø  534Ø          JMP A
Ø551  4365          JMS RSET / INITIALIZE
Ø552  1Ø24  B,      TAD X
Ø553  3416          DCA I MEM / STORE HORIZONTAL AXIS POINTS
Ø554  1Ø24          TAD X
Ø555  1Ø31          TAD INC / INCREMENT COUNTER
Ø556  3Ø24          DCA X
Ø557  3416          DCA I MEM
Ø56Ø  2Ø3Ø          ISZ CNT1
Ø561  5352          JMP B
Ø562  1Ø23          TAD MTEMP
Ø563  3Ø16          DCA MEM
Ø564  5112          JMP TRACE / JUMP TO DISPLAY
Ø565  ØØØØ  RSET,   Ø / INITIALIZATION ROUTINE
Ø566  1Ø27          TAD CNT
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Ø567  3Ø3Ø          DCA CNT1
Ø57Ø  3Ø24          DCA X
Ø571  3Ø25          DCA Y
Ø572  5765          JMP I RSET
                    *Ø6ØØ
Ø6ØØ  4247  MEAN,   JMS INIT / CALCULATE SAMPLE MEAN AND VARIANCE
Ø6Ø1  1443  GO,     TAD I YLOC / ON HISTOGRAM
Ø6Ø2  7Ø1Ø          RAR
Ø6Ø3  7Ø12          RTR / CORRECT FOR HISTOGRAM RISE INCREMENT
Ø6Ø4  ØØ53          AND MASKV / Ø177 IS MAX ACCUMULATION (128)
Ø6Ø5  3Ø7Ø          DCA LOW
Ø6Ø6  4263          JMS SUM / SUM ACCUMULATIONS
Ø6Ø7  2Ø43          ISZ YLOC / AND COMPUTE MEAN
Ø61Ø  2Ø43          ISZ YLOC
Ø611  2Ø21          ISZ NØ1
Ø612  52Ø1          JMP GO
Ø613  43Ø4          JMS AV / AVERAGE AND DISPLAY MEAN IN ACC
Ø614  74Ø2          HLT
Ø615  7Ø41  VAR,    CIA / INVERT & STORE MEAN
Ø616  3Ø24          DCA X
Ø617  4247          JMS INIT / INITIALIZE
Ø62Ø  1443  LOOP,   TAD I YLOC
Ø621  7Ø1Ø          RAR
Ø622  7Ø12          RTR / CORRECT FOR HISTOGRAM RISE INCREMENT
Ø623  ØØ53          AND MASKV / Ø177
Ø624  1Ø24          TAD X
Ø625  751Ø          SPA / COMPUTE (X-MEAN)↑2
Ø626  7Ø41          CIA
Ø627  3277          DCA SS
Ø63Ø  1277          TAD SS
Ø631  4275          JMS SQ
Ø632  4263          JMS SUM / SQUARE & SUM
Ø633  2Ø43          ISZ YLOC
Ø634  2Ø43          ISZ YLOC
Ø635  2Ø21          ISZ NØ1
Ø636  522Ø          JMP LOOP
Ø637  1Ø72          TAD LOR
Ø64Ø  7421          MQL / DISPLAY 24 BIT UNAVERAGED VARIANCE
Ø641  1Ø71          TAD HOR / HIGH ORDER IN ACC
Ø642  74Ø2          HLT / LOW ORDER IN MQ
Ø643  1Ø77          TAD NPT2 / DISPLAY NUMBER OF
Ø644  7421          MQL / SAMPLES (24 BITS)
Ø645  1Ø76          TAD NPT1 / HIGH ORDER IN ACC
Ø646  74Ø2          HLT / LOW ORDER IN MQ
Ø647  ØØØØ  INIT,   Ø / INITIALIZATION ROUTINE
Ø65Ø  73ØØ          CLA CLL
Ø651  3Ø71          DCA HOR
Ø652  3Ø72          DCA LOT
Ø653  3Ø67          DCA HIGH
Ø654  3Ø7Ø          DCA LOW
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Ø655  1311          TAD NØØ
Ø656  7Ø41          CIA
Ø657  3Ø21          DCA NØ1
Ø66Ø  1Ø41          TAD YØ
Ø661  3Ø43          DCA YLOC
Ø662  5647          JMP I INIT
Ø663  ØØØØ   SUM,   Ø / 24 BIT ADDER
Ø664  71ØØ          CLL / ENTER WITH NO. IN HIGH & LOW
Ø665  1Ø7Ø          TAD LOW
Ø666  1Ø72          TAD LOR
Ø667  3Ø72          DCA LOR
Ø67Ø  72Ø4          GLK
Ø671  1Ø71          TAD HOR
Ø672  1Ø67          TAD HIGH
Ø673  3Ø71          DCA HOR
Ø674  5663          JMP I SUM
Ø675  ØØØØ   SQ,    Ø / 24 BIT SQUARING ROUTINE
Ø676  7425          MQL MUY
Ø677  ØØØØ   SS,    Ø
Ø7ØØ  3Ø67          DCA HIGH
Ø7Ø1  75Ø1          MQA
Ø7Ø2  3Ø7Ø          DCA LOW
Ø7Ø3  5675          JMP I SQ / EXIT WITH PRODUCT IN HIGH & LOW
Ø7Ø4  ØØØØ   AV,    Ø / 24 BIT DIVIDER
Ø7Ø5  1Ø72          TAD LOR
Ø7Ø6  7421          MQL
Ø7Ø7  1Ø71          TAD HOR
Ø71Ø  74Ø7          DVI
Ø711  1777   NØØ,   1777 / 1Ø24 QUANTIZATION LEVELS
Ø712  77Ø1          CLA MQA
Ø713  57Ø4          JMP IAV / EXIT WITH 12 BIT QUOTIENT IN ACC
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