# IDPAC User's Guide

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CONTENTS

INTRODUCTION.

The idea behind IDPAC is to provide the engineer with an easy-to-use tool that enables him to obtain and analyze parametric models from measured data.

The program is command driven which means that the user always tells the program what to do next, not vice versa. Since the commands can be entered in arbitrary order, no guidance is given. That is no serious disadvantage since you have to know what you are doing to arrive at a proper model. Moreover the commands are rather easy to remember. Extensive error checking is provided so that the user cannot inadvertently hurt himself.

IDPAC performs some 40 commands including data input, plotting, data modification, spectral analysis, maximum likelihood estimation, simulation a.o.

The models mainly dealt with are linear stationary discrete models on the form

$$y(t) = \Sigma \frac{B_i(q^{-1})}{A_i(q^{-1})} u_i(t) + \lambda \frac{C(q^{-1})}{D(q^{-1})} e(t)$$

When IDPAC is used it often happens that a sequence of commands is repeated with only minor changes of the arguments. In such cases a <u>macro</u> command could be defined in order to minimize the typing effort.

A macro is a new command defined as a sequence of normal IDPAC commands. The commands in the sequence may have formal arguments, which are given actual values when the macro is executed. Thus a macro looks much like a subroutine where the statements are IDPAC commands.

IDPAC as presented in this guide is not a final version. Extensions will be made in a near future as for example commands for recursive least-square estimation, test of model order and computation and plot of transfer functions from spectra. Existing commands may also be changed in order to make them more flexible.

SURVEY OF COMMANDS.

Input-output

MOVE moves data and parameter files between different kinds of bulk storage and/or rearranges the columns of a data file.

TEXT transfers text strings from teletype to line printer.

PRINT prints data, parameter and macro files on line printer.

DISP writes data, parameter and macro files on display.

PLOT plots data vectors on display.

PLLOG plots spectra in a logarithmic diagram on display.

DKDLT deletes data and parameter files from disk.

DTDLT deletes data and parameter files from dectape.

Data modification

PLMAG plots parts of a data vector on display and enables the user to change data values.

ADDC adds a constant to a data vector.

SCALE multiplies the elements in a data vector by a constant.

ADDV adds/subtracts/multiplies/divides two data vectors element by element.

CUT cuts out a part of a data file.

SLIDE moves the columns of a data file along each other.

TREND estimates and removes a polynomial trend from a part of a data vector.

FILT computes digital low-, band- and high-pass filters of given order with given cut-off frequencies.

FHEAD displays the file head of a data or parameter file and enables the user to change the file head parameters.

Estimation

STAT computes some statistical properties of a data vector.

ACOF computes autocorrelations for a data vector.

ASPEC computes the autospectrum for a data vector.

CCOF computes cross correlations between two data vectors.

CSPEC computes the amplitude and phase of the cross spectrum between two data vectors.

ML performs least squares and maximum likelihood estimation of multiple input-single output systems.

Simulation

INSI generates data sequences of different types.

PARFI generates a parameter file from teletype input.

DSIM simulates multiple input-single output discrete systems.

Model analysis

DETER simulates the deterministic part of a multiple input-single output discrete system.

RESID checks independence and normality of residuals.

CASP computes the noise spectrum of a discrete system.

Miscellaneous

MACRO starts the definition of a macro.

CLOSE ends the definition of a macro.

DEFI displays the reserved variables and enables the user to change their values.

ERROR enables/disables printout of extensive error messages.

MACOM enables/disables printout of the commands in an executing macro.

LPCOM enables/disables printout of correct commands on line printer.

TIME enables/disables plotting of data versus time instead of versus sample number.

STOP terminates the operation of IDPAC.

Parameter files contain the following information:

The number of A-, B-, C- and D-polynomials
The number of parameters in each polynomial
The number of time delays for the B-polynomials
The number of parameters estimated and the number of data used for the estimation
A-polynomials (if any)
B-polynomials (if any)
C-polynomials (if any)
D-polynomials (if any)
Noise factor and loss function (if any)
Initial values for the output (if any), i.e. y(0), y(-1), y(-2) ...

Macro files are written in ASCII format without file head. Every record contains one command line.

# COMMAND DESCRIPTIONS.

## Introduction.

The program writes a ready sign (>) when it is ready to accept a new command.
Some commands have subcommands, i.e. internal commands. A subcommand is expected when the ready sign is written a few steps to the right of the left hand margin.
More than one command may be written on the same line if they are separated by a semicolon (;).

A command generally consists of a command name and 0-25 arguments usually arranged in two groups (output and input groups) separated by a left arrow (←).

The arguments are Hollerith strings, integers, real numbers and certain special characters.
The comma sign has a special meaning. If the ith entry in a command line is a comma sign it is replaced by the ith entry in the previous command.
Files are referred to by a user defined Hollerith string of 1-5 alphanumeric characters starting with a letter.
In the command descriptions FNAM(E) means a general file, DNAM(E) a data file, PNAM(E) a parameter file and MNAM(E) a macro file.
Column numbers in a data file are referred to by one or more integers within parentheses. In the command descriptions column numbers are denoted by a C sometimes followed by one or more indices.

Most commands have optional arguments. These are written within brackets in the command descriptions. Dots (...) are written where the number of arguments is optional.

Mutually excluding arguments are separated by a slash (/).

The following conventions apply to all commands where the output is a data vector:

If the output file name is omitted the output will be placed where the input was fetched.
If an output file name but no column number is given a new file is generated.
If an output file name and a column number are given the new column must replace an old column or be placed immediately to the right of the old ones.

NB. The same file name must not appear on both sides of the left arrow (←).

MOVE

## Purpose

To move data and parameter files between different kinds of bulk storage and/or rearrange the columns of a data file.

## Command

MOVE DEV1 [FNAM1[(C11.. C1N)] [ND]]←DEV2 FNAM2[(C21 .. C2N)]

## Function

The columns C21 to C2N (default all) in the data file FNAM2 are moved from device DEV2 to the columns C11 to C1N (default 1, 2, .. , N) in the data file FNAM1 (default FNAM2) on device DEV1.
ND indicates that the old data in the columns C11 to C1N of FNAM1 are not to be deleted but moved to the right.

## Cautions, restrictions

DEV1 ∈ {DK,DT,PP},DEV2 ∈ {DK,DT,PR} DT is dectape unit 2.
Column numbers cannot be used for parameter files.
Input files may contain up to 20 columns and output files up to 10.

Paper tape used as input must have the following format:

One line with 10 integers (the file head) where the first and second are the number of rows and columns resp. The seventh must be 1. The others are not used by MOVE.
One line for each row in the matrix. The data may be punched in free format. Integers will be converted to real numbers.

## Examples

```
>MOVE DK←DT DATA
>MOVE DK WRK←DK DATA(2 5 3)
>MOVE DK WRK(1 3) ND←DK DATA(4 1)
```

DATA

| | | | | |
|---|---|---|---|---|
| 11.0000 | 21.0000 | 31.0000 | 41.0000 | 51.0000 |
| 12.0000 | 22.0000 | 32.0000 | 42.0000 | 52.0000 |
| 13.0000 | 23.0000 | 33.0000 | 43.0000 | 53.0000 |
| 14.0000 | 24.0000 | 34.0000 | 44.0000 | 54.0000 |
| 15.0000 | 25.0000 | 35.0000 | 45.0000 | 55.0000 |
| 16.0000 | 26.0000 | 36.0000 | 46.0000 | 56.0000 |
| 17.0000 | 27.0000 | 37.0000 | 47.0000 | 57.0000 |
| 18.0000 | 28.0000 | 38.0000 | 48.0000 | 58.0000 |
| 19.0000 | 29.0000 | 39.0000 | 49.0000 | 59.0000 |
| 20.0000 | 30.0000 | 40.0000 | 50.0000 | 60.0000 |

WRK

| | | |
|---|---|---|
| 21.0000 | 51.0000 | 31.0000 |
| 22.0000 | 52.0000 | 32.0000 |
| 23.0000 | 53.0000 | 33.0000 |
| 24.0000 | 54.0000 | 34.0000 |
| 25.0000 | 55.0000 | 35.0000 |
| 26.0000 | 56.0000 | 36.0000 |
| 27.0000 | 57.0000 | 37.0000 |
| 28.0000 | 58.0000 | 38.0000 |
| 29.0000 | 59.0000 | 39.0000 |
| 30.0000 | 60.0000 | 40.0000 |

WRK

| | | | | |
|---|---|---|---|---|
| 41.0000 | 21.0000 | 11.0000 | 51.0000 | 31.0000 |
| 42.0000 | 22.0000 | 12.0000 | 52.0000 | 32.0000 |
| 43.0000 | 23.0000 | 13.0000 | 53.0000 | 33.0000 |
| 44.0000 | 24.0000 | 14.0000 | 54.0000 | 34.0000 |
| 45.0000 | 25.0000 | 15.0000 | 55.0000 | 35.0000 |
| 46.0000 | 26.0000 | 16.0000 | 56.0000 | 36.0000 |
| 47.0000 | 27.0000 | 17.0000 | 57.0000 | 37.0000 |
| 48.0000 | 28.0000 | 18.0000 | 58.0000 | 38.0000 |
| 49.0000 | 29.0000 | 19.0000 | 59.0000 | 39.0000 |
| 50.0000 | 30.0000 | 20.0000 | 60.0000 | 40.0000 |

TEXT

Purpose

To transfer text strings from teletype to line printer (comments, headings etc.).

Command

TEXT NL [FF]

Function

NL lines are read from teletype and written on line printer.
FF indicates that a form feed is wanted before the text is written.

Example

```
>TEXT 3 FF
□
□COMMENT
□
>
```

PRINT

DISP

Purpose

Toprint/display data, parameter and macro files.

Command

PRINT
DISP DNAME[(C1 .. CN)][IF NUM]/ PNAME / MNAME

Function

Data files: The columns C1 to CN (default all) of the data file FNAME are printed/displayed for NUM rows (default all) from the IFth (default 1:st) on in G-format.

Parameter files: The A-, B-, C- and D-polynomials (if any), the number of time lags for the B-polynomials, the noise factor $\lambda$, the value of the loss function, initial values for the output (if any), the number of parameters estimated (if any) and the number of data used for the estimation (if any) are printed/displayed.

Macro files: the commands are printed/displayed as card pictures.

Cautions, restrictions

Not more than five columns of a data file may be displayed at a time.

Examples

```
>PRINT DNAME
>PRINT DNAME(2 3 5) 3 4
>PRINT PNAME
>PRINT MNAME
```

```
DNAME

    11.0000         21.0000         31.0000         41.0000         51.0000
    12.0000         22.0000         32.0000         42.0000         52.0000
    13.0000         23.0000         33.0000         43.0000         53.0000
    14.0000         24.0000         34.0000         44.0000         54.0000
    15.0000         25.0000         35.0000         45.0000         55.0000
    16.0000         26.0000         36.0000         46.0000         56.0000
    17.0000         27.0000         37.0000         47.0000         57.0000
    18.0000         28.0000         38.0000         48.0000         58.0000
    19.0000         29.0000         39.0000         49.0000         59.0000
    20.0000         30.0000         40.0000         50.0000         60.0000

DNAME

    23.0000         33.0000         53.0000
    24.0000         34.0000         54.0000
    25.0000         35.0000         55.0000
    26.0000         36.0000         56.0000

PNAME

A 1:
    1.00000        -1.47111        0.686586

B 1:    (  1 TIME DELAY(S))
    0.982769        0.666896

C 1:
    1.00000       -0.459938        0.000000

LAMBDA                LOSS FCN
    0.901430              81.2577

 5 PARAMETERS ESTIMATED FROM   200 SAMPLES

MNAME

MACRO MNAME FIL(COL) CONST
ADDC FIL(COL)EFNAME CONST
PLOT FIL(COL)
CLOSE
```

É is the line printer representation of ←.

PLOT

Purpose

To plot data vectors on display.

Command

PLOT [HP] DNAM1[(C11 .. C1N)] [[HP] DNAM2[(C21 .. C2N][..]..]

Function

The indicated (default all) column(s) of the data file(s) are plotted on display.
Files preceeded by HP are plotted as histograms.
NPLX* rows are plotted per 'page'. A new page is plotted when a rub-out is received from the teletype. An alt mode terminates the plotting.
YMIN* and YMAX* determinate the vertical scale. If YMIN equals YMAX the program will choose appropriate scales.
The curves are marked in the following way:

| Curve | Mark |
|---|---|
| 1 | □ square |
| 2 | o octagon |
| 3 | Δ triangle |
| 4 | + plus |
| 5 | × cross |
| 6 | * asterisk |
| 7 | - horiz. bar |
| 8 | ! vert. bar |

The marks are omitted if only one curve is plotted.

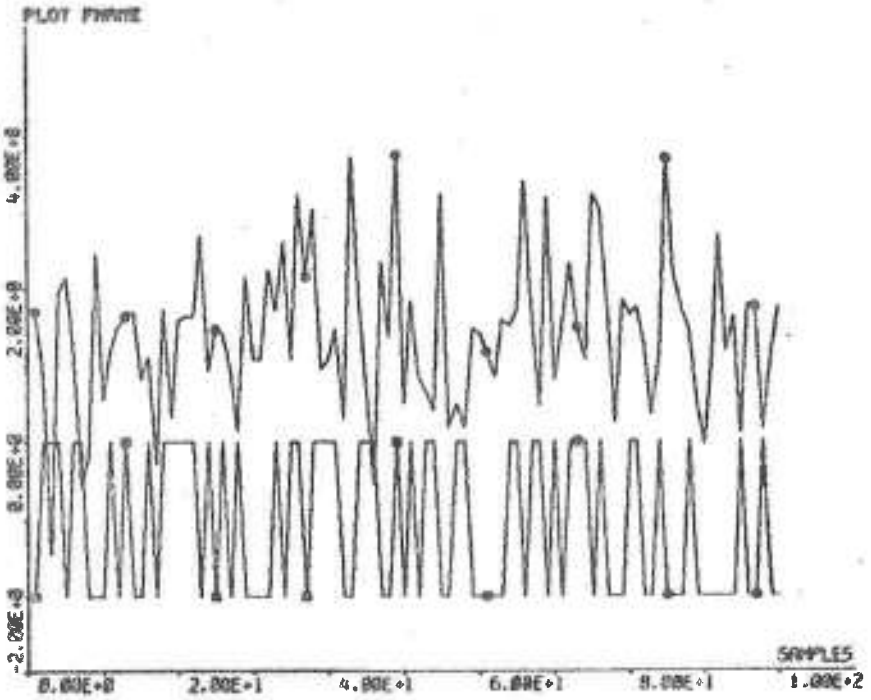
*NPLX, YMIN and YMAX are reserved variables which may be altered by the command DEFI.

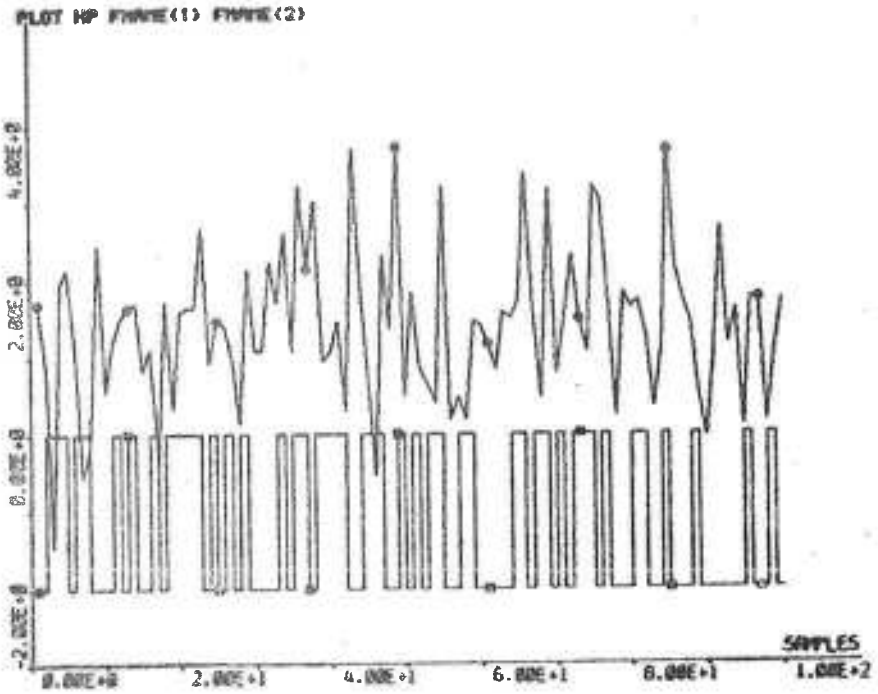
Cautions, restrictions

Even if you give certain values to NPLX, YMIN and YMAX the program will choose among a set of standard scales.

Examples

```
>PLOT FNAME
>PLOT HP FNAME(1) FNAME(2)
```


PLOT FWWE
4.00E+0
2.00E+0
0.00E+0
-2.00E+0
SAMPLES
0.00E+0
2.00E+1
4.00E+1
6.00E+1
8.00E+1
1.00E+2


PLOT HP FWWE(1) FWWE(2)
4.00E+0
2.00E+0
0.00E+0
-2.00E+0
SAMPLES
0.00E+0
2.00E+1
4.00E+1
6.00E+1
8.00E+1
1.00E+2

PLLOG

Purpose

To plot spectra in a logarithmic diagram on display.

Command

PLLOG DNAM1[(C11 .. C1N)] [DNAM2[(C21 .. )] [DNAM3 ..] ..]

Function

The indicated (default all) column(s) of the spectrum file(s) DNAM1 .. are plotted versus angular frequency. The frequency scale always covers the entire frequency range, which is determined from the sample interval and the number of frequencies i.e. the number of data in the file(s).
The amplitude scale is determined by the reserved variables YMIN and YMAX. If YMIN equals YMAX the program will choose appropriate scales.
Zero and negative values of the spectra are replaced by the smallest positive value.
The curves are marked in the following way:

| Curve | Mark |
|---|---|
| 1 | □ square |
| 2 | o octagon |
| 3 | Δ triangle |
| 4 | + plus |
| 5 | × cross |
| 6 | * asterisk |
| 7 | - horiz. bar |
| 8 | \| vert. bar |

The marks are omitted if only one curve is plotted.

Cautions, restrictions

Even if you give certain values to YMIN and YMAX the program will choose among a set of standard scales.
Maximum number of decades is 7.

DKDLT

DTDLT

Purpose

To delete data and parameter files from disk/dectape.

Command

DKDLT FNAM1 [FNAM2 [FNAM3 [..] ..]

DTDLT FNAM1 [FNAM2 [FNAM3 [..] ..]

Function

The files FNAM1 .. are deleted from disk/dectape unit 2.

PLMAG

Purpose

To plot parts of a data vector on display and enable the user to alter data values.

Command

PLMAG DNAME[(C)]

Function

The Cth (default 1st) column in the data file DNAME may be plotted and data values altered using the following subcommands:

B[LOCK] NB defines the number of data to be plotted per page (default 50, max 250).

P[LBEG] NR NB points are plotted from the NRth on.

A[LTER] NR alters the value of the NRth point. The program types the old value of the point on teletype followed by a value sign (□) and a new value may be entered. If no value is entered the old value is retained. The next (previous) point may be altered if a > (<) - sign is entered. The block is replotted when the altering is finished.

N[EXT] the next NB points are plotted.

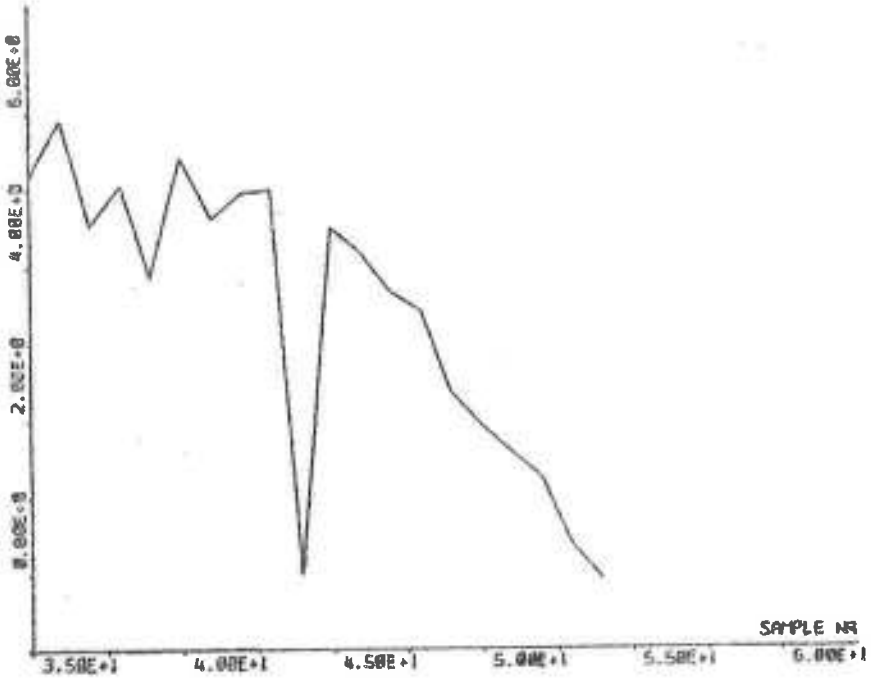
Control is returned to the main program when an alt mode is received.

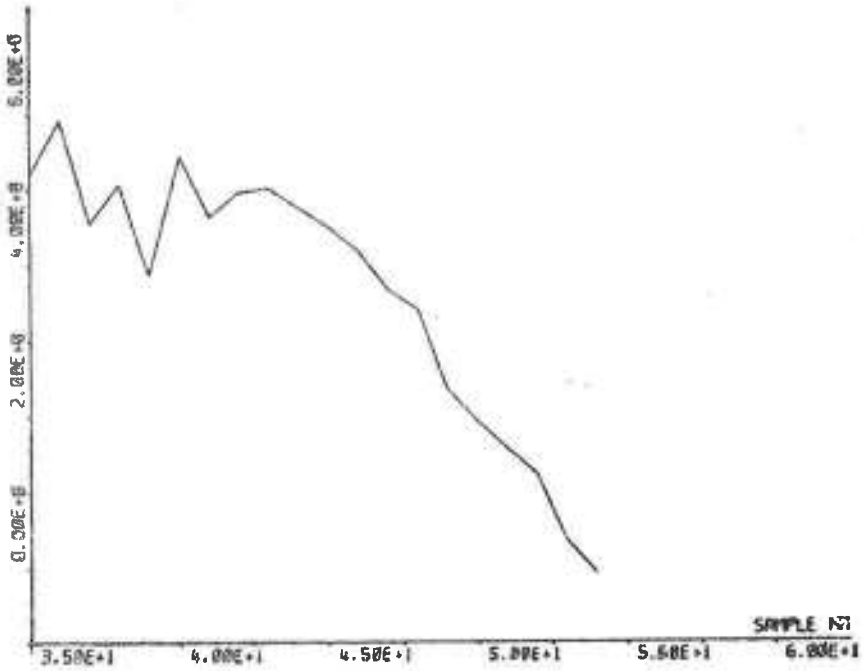
Cautions, restrictions

A data point must be plotted before it can be altered.

Example

```
>PLMAG FILE(2)
        >B 20
        >P 35
        >A 43
         43 OLD VALUE      5.00000     □>
         44 OLD VALUE      0.00000     □4.75
```


6.00E+0
4.00E+0
2.00E+0
0.00E+0
SAMPLE NR
3.50E+1
4.00E+1
4.50E+1
5.00E+1
5.50E+1
6.00E+1


6.00E+0
4.00E+0
2.00E+0
0.00E+0
SAMPLE NR
3.50E+1
4.00E+1
4.50E+1
5.00E+1
5.50E+1
6.00E+1

ADDC

SCALE

Purpose

To add/multiply a data vector by a constant.

Command

ADDC [DNAM1[(C1)]]←DNAM2[(C2)] CONST

SCALE [DNAM1[(C1)]]←DNAM2[(C2)] CONST

Function

Each element in the C2th (default 1st) column of the data file DNAM2 is added/multiplied by the constant CONST. The result is placed in the C1th (default 1st) column of the data file DNAM1. If no output file name is given the result will be placed in DNAM2(C2).

Hint

To subtract the mean value from a column in a data file use STAT to compute the mean value and then use ADDC to subtract it. This may also be done as a zeroth order TREND correction.

ADDV

Purpose

To add, subtract, multiply or divide two data vectors element by element.

Command

ADDV [DNAM1[(C1)]]←DNAM2[(C2)] OP DNAM3[(C3)]
OP ∈ {+,-,*,/}

Function

The C2th (default 1st) column of the data file DNAM2 and the C3th (default 1st) column of the data file DNAM3 are added, subtracted, multiplied or divided element by element. The result is placed in the C1th (default 1st) column of the data file DNAM1. If no output file name is given the result will be placed in DNAM2(C2).

CUT

Purpose

To cut out a part of a data file.

Command

CUT [DNAM1]←DNAM2 IF IL

Function

The rows IF to IL of the data file DNAM2 are moved to the data file DNAM1 (default DNAM2).

Example

>CUT SHORT←FILE 2 7

FILE

| | | |
|---|---|---|
| 11.0000 | 21.0000 | 31.0000 |
| 12.0000 | 22.0000 | 32.0000 |
| 13.0000 | 23.0000 | 33.0000 |
| 14.0000 | 24.0000 | 34.0000 |
| 15.0000 | 25.0000 | 35.0000 |
| 16.0000 | 26.0000 | 36.0000 |
| 17.0000 | 27.0000 | 37.0000 |
| 18.0000 | 28.0000 | 38.0000 |
| 19.0000 | 29.0000 | 39.0000 |
| 20.0000 | 30.0000 | 40.0000 |

SHORT

| | | |
|---|---|---|
| 12.0000 | 22.0000 | 32.0000 |
| 13.0000 | 23.0000 | 33.0000 |
| 14.0000 | 24.0000 | 34.0000 |
| 15.0000 | 25.0000 | 35.0000 |
| 16.0000 | 26.0000 | 36.0000 |
| 17.0000 | 27.0000 | 37.0000 |

SLIDE

Purpose

To move the columns of a data file along each other.

Command

SLIDE [DNAM1]←DNAM2 K1 K2 K3 ... KN

Function

The ith element in the jth column of the output file is the (i+Kj´)th element in the jth column of the input file, where Kj´ is Kj-min(Kl), l = 1, .., N. Kj may be positive or negative.

Cautions, restrictions

The maximum difference between Kk and Kl must not exceed 300. There must be a K for each column in the input file.

Hints

SLIDE may be useful when data files are prepared for ML identification if the input directly influences the output or there is a pure time delay in the process. In the first case you must slide the input one step backwards. Differentiation can be performed in the following way: Make a file with two identical columns and slide them one (or more) steps. Then use ADDV to subtract them.

Example

```
>SLIDE ←FILE -1 0 2
```

FILE

| | | |
|---|---|---|
| 11.[illegible] | 21.[illegible] | 31.0000 |
| 12.[illegible] | 22.[illegible] | 32.0000 |
| 13.[illegible] | 23.[illegible] | 33.0000 |
| 14.[illegible] | 24.[illegible] | 34.0000 |
| 15.[illegible] | 25.[illegible] | 35.0000 |
| 16.[illegible] | 26.[illegible] | 36.0000 |
| 17.[illegible] | 27.[illegible] | 37.0000 |
| 18.[illegible] | 28.0000 | 38.0000 |
| 19.[illegible] | 29.0000 | 39.0000 |
| 20.[illegible] | 30.0000 | 40.0000 |

FILE

| | | |
|---|---|---|
| 11.[illegible] | 22.0000 | 34.0000 |
| 12.[illegible] | 23.0000 | 35.0000 |
| 13.[illegible] | 24.0000 | 36.0000 |
| 14.[illegible] | 25.0000 | 37.0000 |
| 15.[illegible] | 26.0000 | 38.0000 |
| 16.[illegible] | 27.0000 | 39.0000 |
| 17.[illegible] | 28.0000 | 40.0000 |

TREND

Purpose

To estimate and remove a polynomial trend from a part of a data vector.

Command

TREND [DNAM1[(C1)]←DNAM2[(C2)] [IF IL] NO

Function

A polynomial trend of order NO is estimated for the C2th (default 1st) column in the data file DNAM2 between the IFth (default 1st) and the ILth (default last) points. Then the trend is subtracted and the result is placed in the C1th (default 1st) column in the data file DNAM1. If no output file name is given the result will be placed in DNAM2(C2).
If the reserved variable PRINT is nonzero the parameters (with reference to the left end-point of the interval) will be printed on line printer.

Method

A least squares technique is used where the parameters are estimated with reference to the midpoint of the interval.

Reference

Otnes & Enochson, Digital Time Series Analysis, Wiley, 1972.

Cautions, restrictions.

The order of the polynomial must be between 0 and 3

FILT

Purpose

To compute digital low-, band- and high-pass filters of given order with given cut-off frequencies.

Command

```
FILT PNAME ←TYPE NO OMH OML T
           TYPE ∈ {LP,BP,HP}
           For high- (low-) pass filters OMH (OML) is
           omitted
```

Function

A filter of type TYPE, order NO and with the cut-off frequencies OMH and OML rad/s (high and low cut-off frequency resp.) is computed for a sample period of T s. The result is placed as A- and C-polynomials in the parameter file PNAME.

Method

A bilinear z-transform method is used which eliminates aliasing effects. The Laplacian variable in the continuous filter transfer function H(s) is substituted by $2(1-z^{-1})/T(1+z^{-1})$ giving the discrete transfer function H(z). The cut-off frequencies $\omega_i$ are substituted by the 'pseudo frequencies' $\nu_i = (2/T)\tan(\omega_i T/2)$. Band-pass filters and high- or low-pass filters of higher order than 1 are computed by multiplication of 1st order filters.

Reference

Roggenbauer, Seifertz, Olsson: Identification and Adjoint Problems of Process Computer Control, Re-7222, Lund Inst. of Tech., Div. of Aut. Control, Lund.

Cautions, restrictions

Maximum filter order is 10. Cut-off frequencies higher than 1/(2T) rad/s or lower than 1/(1000T) rad/s will not be accepted by the command.

Hints

A diagram of the amplitude of the filter spectrum may be obtained via the CASP and PLLOG commands.
The filtering is performed with the command DSIM.
Filtering of the type $y_f(t) = y(t) + a \cdot y(t-n)$ can be performed using the SLIDE, SCALE and ADDV commands.

Example

```
>FILT HPFIL←HP 1 0.5 0.1
>DSIM YF←HPFIL DATA (4)
```

FHEAD

Purpose

To display file head parameters of data and parameter files and enable the user to change them.

Command

FHEAD FNAME

Function

The file head parameters of the file FNAME are written on display with some explanations. The value of parameter i may be altered by the subcommand:
I VALUE
Control is returned to the main program when a line is terminated by an alt mode.

Cautions, restrictions

The first and second parameters (i.e. the number of rows and the number of columns) must not be increased.

Example

```
>FHEAD FILE
     >5 070973
     >6 0930
```

STAT

Purpose

To compute some statistical properties of a data vector.

Command

STAT DNAME[(C)]

Function

The sum, mean, variance, standard deviation, minimum and maximum for the Cth (default 1st) column in the data file DNAME are computed and displayed. The results will also be printed on line printer if the reserved variable PRINT is nonzero.

Example

```
>STAT UT(2)
```

```
UT    ( 2)

SUM      =  -216.508
MEAN     =  -2.16508
VARIANCE =   424.615
ST.DEV.  =   20.6062
MINIMUM  =  -43.0363
MAXIMUM  =   48.3345
```

ACOF

Purpose

To compute autocorrelations for a data vector.

Command

ACOF DNAM1[(C1)]←DNAM2[(C2)] NOL

Function

The autocorrelations for the C2th (default 1st) column in the data file DNAM2 are computed for 0,1,..,NOL lags and placed in the C1th (default 1st) column in the data file DNAM1.

Method

The autocovariances are computed using

$$R_{xx}(\tau) = \frac{1}{n} \sum_{j=\tau+1}^{n} (x_j - m)(x_{j-\tau} - m) \qquad \tau = 0,1,..,NOL$$

where n is the number of data in DNAM2(C2)

$x_j$ is the jth point in DNAM2(C2)

m is the mean value of the data in DNAM2(C2)

Then the autocorrelations are computed from

$$r_{xx}(\tau) = \frac{R_{xx}(\tau)}{R_{xx}(0)} \qquad \tau = NOL, ..,0$$

Cautions, restrictions

Maximum number of lags is 500.

ASPEC

Purpose

To compute the autospectrum for a data vector.

Command

ASPEC DNAM1[(C1)]←DNAM2[(C2)] NOL

Function

The smoothed autospectrum for the C2th (default 1st) column in the data file DNAM2 is computed using the autocovariances for up to NOL lags. The spectrum is computed for NOF frequency intervals, where NOF is a reserved variable. A Tukey window is used for the smoothing. The result is placed in the C1th (default 1st) column in the data file DNAM1.

Method

The autocovariances are computed as described for the command ACOF. Then the autospectrum is computed from

$$\Phi(\omega) = 2\Delta T\left\{R_{xx}(0) + \sum_{\tau=1}^{NOL} R_{xx}(\tau)\cos(\omega\Delta T\tau)\left(1 + \cos\left(\frac{\pi\tau}{NOL+1}\right)\right)\right\}$$

where $\omega$ is the frequency in rad/s

$\Delta T$ is the sample period in s

$R_{xx}(\tau)$ is the autocovariance for lag $\tau$.

The bandwidth $B = 4/(3(NOL+1)\Delta T)$ and the degrees of freedom $D = 8N/3(NOL+1)$.

Cautions, restrictions

Data files with zero sample period are not accepted as input files.

Maximum number of lags and maximum number of frequencies are 500.

CCOF

Purpose

To compute cross correlations between two data vectors.

Command

CCOF DNAM1[(C1)]←DNAM2 (C21 C22) NOL

or

CCOF DNAM1[(C1)]←DNAM2[(C2)]DNAM3[(C3)] NOL

Function

The cross correlations between the C21th and the C22th columns in the data file DNAM2 or between the C2th (default 1st) column in DNAM2 and the C3th (default 1st) in DNAM3 are computed for NOL lags, and placed in the C1th (default 1st) column in the data file DNAM1.

Method

The cross covariances are computed using

$$R_{xy}(\tau) = \frac{1}{N} \sum_{j=\max(1,1-\tau)}^{\max(N-\tau,N)} (x_j - m_x)(y_{j+\tau} - m_y) \qquad \tau = -NOL,\ldots,NOL$$

where N is the number of data in each input vector

$x_j$, $y_j$ are the jth data values

$m_x$, $m_y$ are the mean values of the data in the input vectors.

Then the cross correlations are computed as

$$r_{xy}(\tau) = \frac{R_{xy}(\tau)}{\sqrt{R_{xx}(0) \cdot R_{yy}(0)}}$$

Cautions, restrictions

The maximum number of lags is 500.

Hint

If y is the output of a system for a white noise input u then $r_{uy}$ is the impulse response.

CSPEC

Purpose

To compute the amplitude and phase of the cross spectrum between two data vectors.

Command

CSPEC DNAM1[(C11 C12)]←DNAM2(C21 C22) NOL [IALIGN]

or

CSPEC DNAM1[(C11 C12)]←DNAM2[(C21)]DNAM3[(C31)] NOL [IALIGN]

Function

The amplitude and phase of the smoothed cross spectrum between the C21th and C22th columns in the data file DNAM2 or between the C21th (default 1st) column in DNAM2 and the C31th (default 1st) column in DNAM3 are computed for NOF frequency intervals from cross covariances computed for NOL lags. NOF is a reserved variable (default value 100, may be altered by the command DEFI).
IALIGN is the number of lags necessary to align the two processes so that the largest cross covariance is centered at zero. The default value is 0.
A Tukey window is used for the smoothing.
The amplitude and phase are placed as the C11th and C12th (default 1st and 2nd) columns in the data file DNAM1.

Method

The cross covariances are computed as described for the command CCOF. Then the co- and quadrature spectra are computed from

$$EV(k) = 0.5\left(R_{xy}(k+IALIGN) + R_{xy}(-k+IALIGN)\right)$$

$$OD(k) = 0.5\left(R_{xy}(k+IALIGN) - R_{xy}(-k+IALIGN)\right)$$

$$k = 0, \ldots, NOL-|IALIGN|$$

$$CS(\omega) = 4\Delta T\left\{EV(0) + 0.5\sum_{\tau=1}^{NOL'} EV(\tau)\cos(\omega\Delta T\tau)\left(1 + \cos\frac{\pi\tau}{NOL'}\right)\right\}$$

$$QS(\omega) = 2\Delta T\sum_{\tau=1}^{NOL'} OD(\tau)\sin(\omega\Delta T\tau)\left(1 + \cos\frac{\pi\tau}{NOL'}\right)$$

Then the amplitude and phase are computed from

$$AMP(\omega) = \sqrt{CS(\omega)^2 + QS(\omega)^2}$$

$$PHASE(\omega) = \arctan\left[-\left(QS(\omega)/CS(\omega)\right)\right]$$

<u>Cautions, restrictions</u>

Maximum number of time lags and maximum number of frequency intervals are 500.
Data files with zero sample interval will not be accepted by the command.
It is also impossible to compute the cross spectrum between two columns from data files with different sample intervals.

ML

Purpose

To perform maximum likelihood identification on multiple input - single output systems on the form

$$A(q^{-1})y(t) = B_1(q^{-1})u_1(t) + \ldots + B_m(q^{-1})u_m(t) + \\ + \lambda C(q^{-1})e(t)$$

Command

ML PNAME←DNAME[(C11 .. C1N)] NO [SA/NA]

Function

A model of order NO is estimated for the columns C11 to C1N (default all) in the data file DNAME. The last column is assumed to contain the system output, the other ones inputs. SA indicates that access to subcommands is desired. NA (the default value) indicates that access to subcommands is not desired. NA is useful only as an actual argument in a macro.
The result is placed in the parameter file PNAME.

Subcommands:

INVAL ABCI/C PNAME

Starting values for the parameters are fetched from the parameter file PNAME.
ABCI indicates that all parameters shall have starting values.
C indicates that only C parameters shall have starting values, meaning that the first iteration will be a least squares estimation of the A and B parameters.
If INVAL is not used all parameters have the starting value 0.0.

FIX A 2 3 B 22 23 ...

The indicated parameters are forced to remain at their starting values.

EXIT

No identification is performed but control is returned to the main program.

The estimation is started when a line is terminated by an alt mode.

Reserved variables used (default values underlined):

INIML 1 initial values for the output will be estimated.
<u>0</u> no estimation.

PRIML <u>0</u> loss function and lambda for starting values are printed as well as the final estimate with derivatives, second derivative matrix and inverse of the second derivative matrix. The final estimate is also displayed.
1 0 + the estimate printed for each iteration.
2 1 + derivatives, second derivative matrix and inverse of the second derivative matrix printed for each iteration. Each estimate is dispalyed.

LIML 1 the residuals will be limited to 3·lambda in each iteration, i.e. if $\varepsilon(t)>3\lambda$ then $\varepsilon(t) = 3\lambda$.
<u>0</u> no limitation.

ITML maximum number of iterations (default 20).

With the SA option these variables are displayed and may be altered. They may also be altered by the DEFI command.

<u>Method</u>

A maximum likelihood estimate of the parameters in the model

$$A(q^{-1})y(t) = B_1(q^{-1})u_1(t) + \ldots + B_m(q^{-1})u_m(t) + \\ + \lambda C(q^{-1})e(t)$$

is obtained by minimizing the loss function

$$V(\theta) = \frac{1}{2} \Sigma \varepsilon^2(t)$$

where

$$C(q^{-1})\varepsilon(t) = A(q^{-1})y(t) - B_1(q^{-1})u_1(t) - \ldots - B_m(q^{-1})u_m(t)$$

and

$$\theta = (a_1, \ldots, a_n, b_{11}, \ldots, b_{1n}, \ldots, b_{m1}, \ldots, b_{mn}, c_1, \ldots, c_n)$$

The maximum likelihood estimate of $\lambda$ will be

$$\hat{\lambda}^2 = \frac{2}{N} V(\hat{\theta})$$

where $\hat{\theta}$ is the minimum point of V.
The minimization is performed iteratively by a combined Gauss-Newton and Newton-Raphson algorithm.
The parameter accuracy is estimated by

$$\sigma^2_{\theta_i} = \lambda^2 [V_{\theta\theta}(\hat{\theta})]^{-1}_{ii}$$

The convergence criteria are

$$\max_i \left| \frac{\Delta\theta_i}{\theta_i} \right| \leq 10^{-4} \quad \text{or} \quad |\Delta V| \leq 10^{-6}$$

The first step of the iteration is a least squares estimate of the parameters of $A(q^{-1})$ and $B_i(q^{-1})$ provided that the subcommand INVAL ABCI is not used.

## References

Åström, K.J., Bohlin, T., and Wensmark, S.: Automatic Construction of Linear Stochastic Dynamic Models for Stationary Processes with Random Disturbances using Operating Records, Report TP 18.150 (1965), IBM Nordic Laboratory, Sweden.

Gustavsson, I.: Parametric Identification of Multiple Input, Single Output Linear Dynamic Systems, Report 6907 (1969), Division of Automatic Control, Lund Institute of Technology, Lund, Sweden.

Almqvist, R.: Program för maximum-likelihood identifiering på PDP-15 (Program for Maximum Likelihood Identification on PDP-15), Report RE-103 (1972), Master Thesis, Division of Automatic Control, Lund Institute of Technology, Lund, Sweden.

## Cautions, restrictions

Maximum order is 9, maximum number of inputs is 8 and maximum total number of estimated parameters is 25 including fixed parameters and initial values for the output. There is no maximum for the number of input data.

## Hints

1. If just a least squares estimation is wanted, use no initial values for the A and B parameters and set PRIML and ITML to 1.
2. Time series analysis can be carried out if only one column is indicated since the number of inputs is always assumed to be one less than the number of columns specified and the output is always the last column specified.
3. A moving average model y = Ce can only be estimated in the following way:
   Fix all $a_i$, $i = 1,\ldots,n$
   Give any nonzero initial values to $c_i$, $i = 1, \ldots, n$.

4. Known relations between parameters can be introduced as indicated by the following examples:

   Ex.1 Known relation: $b_1u_1(t-1) + 1.5b_1u_2(t-1)$
   Develop a signal: $\tilde{u}(t-1) = u_1(t-1) + 1.5u_2(t-1)$
   and then estimate $b_1\tilde{u}(t-1)$

   Ex.2 Known relation: $a_1y(t-1) + 3a_1y(t-2)$
   Develop a signal: $\tilde{y}(t-1) = y(t-1) + 3y(t-2)$
   and use this signal as an input signal and estimate the coefficient $a_1$.

5. Notice that the same technique can be used for e.g. the estimation of the coefficients $a_{12}$ and $a_{13}$ in the model

$$y(t) + a_1y(t-1) + a_{12}y(t-12) + a_{13}y(t-13) =$$
$$= b_1u(t-1) + e(t) + c_1e(t-1)$$

   In this case develop a signal $\tilde{u}(t-1) = y(t-12)$ and use this signal as an input signal to estimate $a_{12}$ and $a_{13}$.

6. If the experiment/simulation is not started in steady state with the levels subtracted from the data it might be useful also to estimate initial values of the difference equation

$$A(q^{-1})y(t) = B_1(q^{-1})u_1(t) + \ldots + B_m(q^{-1})u_m(t) +$$
$$+ \lambda C(q^{-1})e(t)$$

   i.e. the values $y(0)$, $y(-1)$, ..., $y(1-n)$, where $n$ is the order of the system.

INSI

Purpose

To generate data sequences of different types for use as inputs.

Command

INSI DNAME[(C)] NR

Function

A sequence of NR data is generated and placed in the Cth (default 1st) column of the data file DNAME.
Type of sequence and the parameters needed for that type are entered as a subcommand. If no parameters are entered default values are used.
The point where the sequence starts, starting value for the random number generator, amplitude and sample period are fetched from the reserved variables IFP, NU, AMP and DELTA resp. These variables are displayed and may be altered before the sequence type is entered if the name and a new value of a variable are entered. (They may also be altered by the command DEFI.)
Subcommands:
(default values for the parameters within paranthesis)

PRBS [NBIT ISTART [KNEP]]

- NBIT - number of bits in the shift register, min. 3, max. 17 (7).
- ISTART - specifies starting point in the sequence 1, 2, 3 or 4 (1)
- KNEP - FOA-trix is used (no KNEP)

NORM [MEAN SIGMA]

- MEAN - mean value (0.0)
- SIGMA - standard deviation (1.0)

RECT [A B]

- A - lower boundary (0.0)
- B - upper boundary (1.0)

SINE [OMEGA FI]

OMEGA - angular frequency (1.0 rad/s)

FI - phase (0.0 rad)

ZERO

STEP

RAMP [A B]

A - constant term (0.0)

B - linear term (1.0)

PULSE [LENGTH]

LENGTH - pulse length (1)

SRTW [PS]

PS - change-of-sign probability (0.5)

Cautions, restrictions

Maximum number of points is 3000.

Example

```
>INSI FIL 200
            >AMP 2.5
            >PRBS
```

PARFI

Purpose

To generate a parameter file from teletype input.

Command

PARFI PNAME TSAMP

Function

A parameter file PNAME with a sample period of TSAMP is generated from teletype input.
The polynomials are assumed to be typed in the following way:
An A, B, C or D followed by the coefficients (real numbers) for one polynomial. The number of coefficients need not be equal in different polynomials. The number of time delays (if any) for B polynomials may be inserted as an integer between the B and the first coefficient (separated by spaces).
The polynomials may appear in any order but if e.g. several B polynomials are used they will be written into the parameter file in the order they were entered.
The noise coefficient $\lambda$ may be entered after LAM (default value is 1.0). Initial values for the output may be entered after INIT.
The value of a loss function may be entered after LOSS.
The number of parameters estimated and the number of samples used for the estimation may be entered after NPAR and NDAT (default values are 0).
An alt mode indicates that the input is finished.

Cautions, restrictions

A- and C-polynomials must start with the coefficients $a_o$ and $c_o$. B-polynomials start with the coefficient $b_k$ where k is the number of time delays specified.
If an error is detected just retype from the erroneous entry.

Maximum number of coefficients in one polynomial is 20.
Maximum number of polynomials is 10 of each kind.

Example

```
>PARFI PNAM 0.5
     >A 1.0 -1.5 0.7
     >B 1 1.0 0.5
     >C 1.0 -0.5
     >LAM 0.9
```

```
PNAM

A 1:
     1.00000        -1.50000        0.700000

B 1:    C   L  TYP  DELAY(S)
     1.00000        0.500000

C 1:
     1.00000       -0.500000

LAMBDA                 LOSS FCN
   0.900000             0.000000
```

DSIM

Purpose

To simulate multiple input - single output discrete systems on the form

$$y(t) = \Sigma \frac{B_i(q^{-1})}{A_i(q^{-1})} u_i(t) + \lambda\Sigma \frac{C_i(q^{-1})}{D_i(q^{-1})} e_i(t)$$

Command

```
DSIM DNAM1[(C11)]←PNAME [NP] DNAM2[(C21 22 ..)]
    [DNAM3[(C31 ..)] ..... ]
```

Function

The discrete system PNAME is simulated for NP points (default the number of data in the shortest input file) using the indicated (default all) columns in the data files DNAM2 .. as inputs and noise. Inputs are assumed to appear first and noise last. The output is placed in the C11th (default 1st) column of the data file DNAM1.

Method

The simulation is performed as a superposition of simulations of single input - single output systems with the initial values zero and the transient from the initial values for the output if such are present in PNAME.
If PNAME contains only one A polynomial it is used for all the inputs.
If no D polynomial(s) is present, the A polynomial(s) is used instead.

Cautions, restrictions

The maximum number of points that can be simulated is 3000.
Initial values for the output must not be used when the parameter file contains more than one A polynomial.

DETER

Purpose

To simulate the deterministic part of a discrete system, i.e.

$$y(t) = \Sigma \frac{B_i(q^{-1})}{A_i(q^{-1})} u_i(t)$$

Command

DETER DNAM1[(C11)]←PNAME [NP] DNAM2[(C21 C22 ..)][DNAM3[..]..]

Function

The deterministic part of the discrete system PNAME is simulated for NP points (default the number of points in the shortest input file) using the indicated (default all) columns in the data files DNAM2, .. as inputs. The output is places in the C11th (default 1st) column of the data file DNAM1.

Method

The simulation is performed as a super position of simulations of single input - single output systems with the initial values for the output zero and the transient from the initial values if such are present in PNAME.
If PNAME contains only one A polynomial it is used for all inputs.

Cautions, restrictions

The maximum number of points that can be simulated is 3000.
Initial values for the output must not be used when the parameter file contains more than one A polynomial.

Hint

The deterministic model error may be obtained if the deterministic output is subtracted from the measured output using the ADDV command.

RESID

Purpose

To test the whiteness of the residuals and independence between the residuals and the inputs of an estimated model.

Command

RESID DNAM1[(C11)]←PNAME DNAM2[(C21 22 ..)] NOL

Function

The residuals are computed for the parameter file PNAME using the indicated (default all) columns of the data file DNAM2 as measured inputs and output. The output must be the last column specified or, if no columns are specified, the last column in the file. The residuals are placed in the C11th (default 1st) column of the data file DNAM1.
The normality and whiteness of the residuals are tested, the autocorrelations for the residuals and the cross correlations between the residuals and the input(s) (if any) are computed for up to NOL lags. Then the independence between the residuals and the input(s) is tested.
The autocorrelations and cross correlations are plotted on display along with information about test quantities and number of degrees of freedom. The information is divided into pages. A key on the keyboard (preferably rubout) must be depressed when a new page is wanted.
The information displayed as well as more detailed information from the test of normality of the residuals is printed on line printer if the reserved variable PRINT is nonzero. See the reserved variable list..

Method

The residuals are computed using the formula

$$\varepsilon(t) = \frac{A(q^{-1})}{C(q^{-1})} y(t) - \Sigma \frac{B_i(q^{-1})}{C(q^{-1})} u_i(t)$$

The normality is tested by a chi-square goodness-of-fit test. The observations are grouped into K intervals forming a frequency histogram. The observed frequency in the ith class interval is called $f_i$ and the expected one $F_i$ if the true distribution was normal. The quantity

$$X^2 = \sum_{i}^{K} \frac{(f_i - F_i)^2}{F_i}$$

is approximately $\chi^2(K-3)$. The number of class intervals is chosen depending on the number of observations.

The number of changes of sign of the residuals is computed and is

$$N\left(\frac{M-1}{2}, \frac{\sqrt{M-1}}{2}\right)$$

where M is the number of observations. To test the independence of the residuals

$$\sum_{1}^{5} r_\varepsilon^2(\tau)$$

is computed. This quantity is $\chi^2(5)$.

To test the independence between the residuals and the input(s) $x^T P_x^{-1} x$ is computed where

$$x = \begin{vmatrix} r_{\varepsilon u}(j) \\ \vdots \\ r_{\varepsilon u}(j+m-1) \end{vmatrix}$$

and

$$P_x = \frac{1}{N} \begin{vmatrix} r_{uu}(0) & \cdots\cdots\cdots & r_{uu}(m-1) \\ r_{uu}(1) & r_{uu}(0) \cdots\cdots & r_{uu}(m-2) \\ & & \\ r_{uu}(m-1) & \cdots\cdots\cdots & r_{uu}(0) \end{vmatrix}$$

This quantity is asymptotically $\chi^2(m)$.
The cross correlation function is defined by

$$r_{\varepsilon u}(\tau) = E[\varepsilon(t) \cdot u(t+\tau)]$$

For positive $\tau$, j is chosen equal n+1 where n is the order of the system in PNAME. m is chosen to 5. The test quantity is also computed for negative $\tau = -4, \ldots, 0$.
For both the autocorrelation and cross correlation functions the two sigma limits $(= 1.96(1/\sqrt{M}))$ are plotted, indicating the region inside which the estimates of the correlations should be with 95% probability if the residuals (and the input(s)) are independent.

Reference

J.S. Bendat and A.G. Piersol: Measurement and analysis of random data, Wiley, New York, 1966.

Cautions, restrictions.

The length of the input file must not exceed 3000 samples.

Hints

The test quantity for negative $\tau$ can indicate whether the original system is under feedback or not. A large test quantity may indicate feedback.
If the parameter file is a unit system, i.e. contains only one A parameter and one C parameter (both equal to 1.0), the independence and normality of a time series may be tested.

CASP

Purpose

To compute the noise spectrum of a parametric model, i.e. the spectrum for $y(t) = C(q^{-1})/A(q^{-1}) \cdot e(t)$.

Command

CASP DNAME[(C)]←PNAME

Function

The spectrum of the noise part of the file PNAME is computed for NOF frequencies from 0 to $\pi/T$ rad/s. (NOF is a reserved variable and T is the sample period.) The spectrum is placed in the Cth (default 1st) column of the data file DNAME.

Method

The spectrum $\Phi_y(\omega)$ is computed from

$$\Phi_y(\omega) = H(e^{i\omega T})H(e^{-i\omega T})\Phi_e(\omega)$$

where $H(z) = C(z)/A(z)$

$\Phi_e(\omega) = 1$

MACRO
CLOSE

Purpose

To define a new command as a sequence of existing commands with formal arguments.

Commands

MACRO MNAME [ARG1 [ARG2 [...]...]
CLOSE

Function

A macro file called MNAME is created from all commands succeeding the MACRO command until a CLOSE command is entered.
ARG1 ... are the names of formal arguments used within the macro. All other arguments in the macro are flagged as actual arguments.
When defined, MNAME may be used as any other command.

Cautions, restrictions

Macros may not be nested.
A macro must not have the same name as a normal command.

Hint

The commands in the macro will be echoed on the teletype when the macro is executed if the command MACOM ON is entered.

Example

```
>MACRO MAC FIL(COL) CONST
>ADDC  FIL(COL)←FNAME CONST
>PLOT FIL(COL)
>CLOSE
>MAC DATA(2)  0.5
```

DEFI

Purpose

To display the values of the reserved variables and enable the user to change them.

Command

DEFI

Function

The names and values of all reserved variables are displayed. Then the name and new value of a variable to be changed may be entered as a subcommand. All names and values are redisplayed after each entry.
Control is returned to the main program when an alt mode is recieved.

Example

```
>DEFI
        >NPLX 250
        >YMAX 25.
```

ERROR
MACOM
LPCOM
TIME

Purpose

To alter the switches for error, macro and line printer output and plotting versus time.

Commands

ERROR ON/OFF
MACOM ON/OFF
LPCOM ON/OFF
TIME ON/OFF

Function

ERROR enables/disables printout of extensive error messages (explanations of the error codes).
MACOM enables/disables printout of commands in an executing macro.
LPCOM enables/disables printout of correct commands on line printer.
TIME enables/disables plotting of data versus time instead of versus sample number.

When IDPAC is started ERROR and MACOM are ON and LPCOM and TIME are OFF.

RESERVED VARIABLES

In order to make some commands shorter and easier to remember some parameters concerning e.g. plotting and printout printout which are not often changed have been put in a special area for reserved variables. The command DEFI and a few other commands that use several reserved variables enables the user to alter the value of these variables.

The names, meaning and default values of the reserved variables are listed below.

NPLX number of points (TIME OFF) or number of seconds (TIME ON) per plot page (default 100).

NOF number of frequency intervals for which spectra will be computed (default 100).

INIML determines if the ML-identifier shall estimate initial values for the output (default 0)
- 0 no estimation
- 1 estimation

PRIML print parameter for the ML-identifier (default 0)
- 0 loss function and lambda for starting values are printed as well as the final estimate with derivatives, second derivative matrix and inverse of the second derivative matrix. The final estimate is also displayed.
- 1 0 + the estimate for each iteration.
- 2 1 + derivatives, second derivative matrix and inverse of the second derivative matrix for each iteration. Each estimate is dispalyed.

LIML determines if the residuals shall be limited (default 0)
- 0 no limitation
- 1 the residuals will be limited to $3\lambda$ in each iteration, i.e. if $\varepsilon(t)>3\lambda$ then $\varepsilon(t)=3\lambda$.

ITML maximum number of iterations for the ML-identifier (default 20).

IFP the point where a data sequence from INSI starts (default 1).

NU starting value for random number generator (default 9).

PRINT print parameter for STAT, TREND and RESID (default 0)

0 no printout

1 STAT: displayed information printed

TREND: coefficients for the correction polynomial printed

RESID: mean, st. dev., deg. of freedom, test quantity, sqewness and kurtosis from the test of normality + displayed information printed

2 1 + (for RESID) absolute and cumulative frequencies from the test of normality printed.

YMIN minimum value for plots (default 0.0).

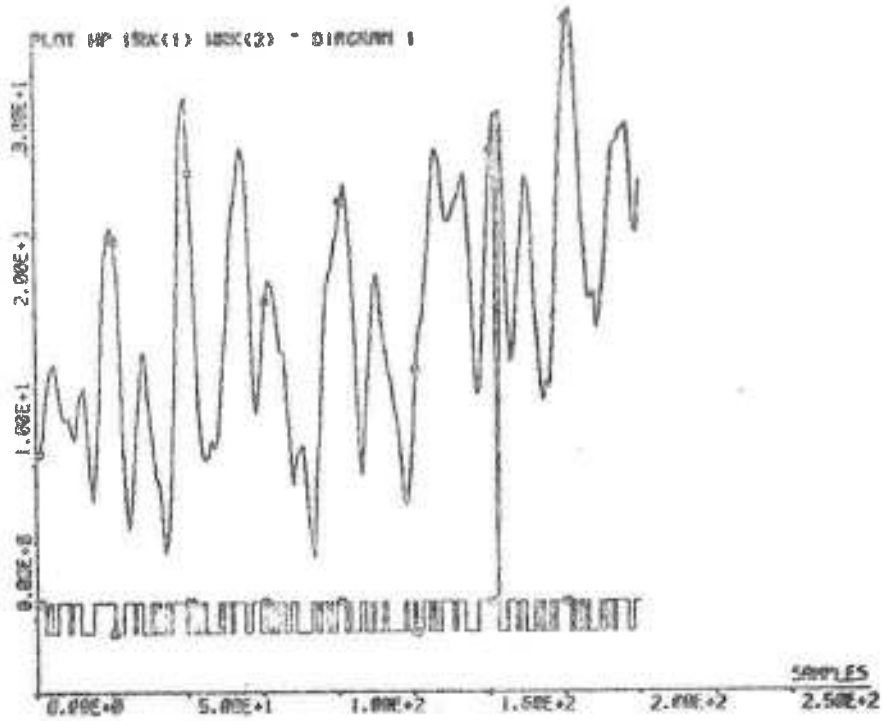
YMAX maximum value for plots (default 0.0).

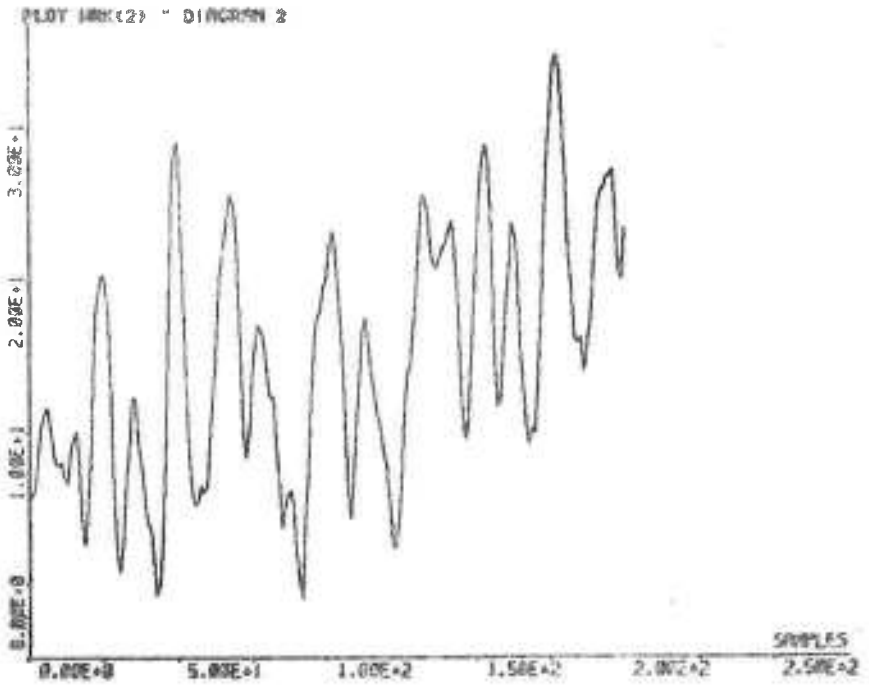
AMP amplitude for data sequencies from INSI (default 1.0).

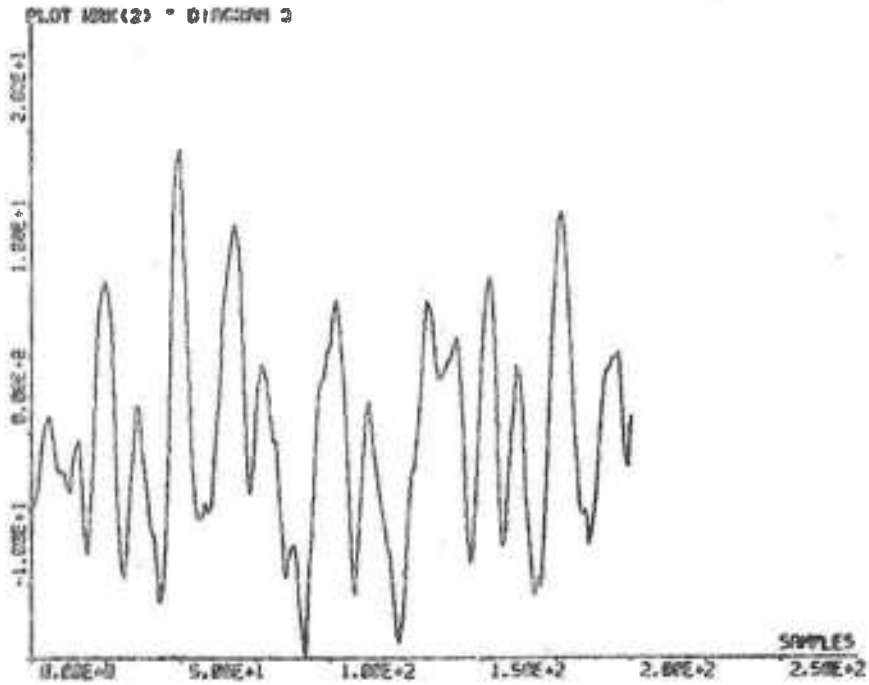
DELTA sample period for data sequencies from INSI (default 1.0).

```
DOS-15 V1A
$A DKA 3,13,14/NON 4,5,7

$BUFFS 6

$E IDPAC

IDPAC V1D


>"       FETCH DATA FROM DECTAPE
>
>MOVE DK WRK←DT DATA(1 3)
>
>"       PLOT THE DATA
>
>PLOT WRK
>
>"       CHANGE THE NUMBER OF POINTS PER PAGE TO 200
>
>DEFI
    >NPLX 200
>PLOT HP WRK(1) WRK(2) " DIAGRAM 1
>
>"       ALTER A FALSE VALUE
>
>PLMAG WRK(2)
    >B 20
    >P 142
    >A 152
      152 OLD VALUE   33.1303     #>
      153 OLD VALUE  0.000000     #34.>
      154 OLD VALUE   33.2624     #
>PLOT WRK(2) " DIAGRAM 2
>
>"       REMOVE THE TREND
>
>TREND ←WRK(2) 50 200 1
>PLOT WRK(2) " DIAGRAM 3
>
>"       PERFORM MAXIMUM - LIKELIHOOD IDENTIFICATION
>
>ML ML1←WRK 1 " PAGE 6.1.5
>ML ML2←WRK 2 " PAGE 6.1.6
>ML ML3←WRK 3 " PAGE 6.1.6
>
>"       TEST THE MODELS
>
>RESID RES1←ML1 WRK 20 " DIAGRAM 4,5
>RESID RES2←ML2 WRK 20 " DIAGRAM 6,7
>RESID RES3←ML3 WRK 20 " DIAGRAM 8,9
>
>"       THE PROCESS SEEMED TO BE OF SECOND ORDER
>"       TRY A SECOND ORDER MODEL WITH C1 FIXED TO 0.0
>
>ML ML21←WRK 2 SA " PAGE 6.1.10
    >FIX C 1
>RESID RES21←ML21 WRK 20 " DIAGRAM 10,11
```

```
>
>"        COMPUTE THE DETERMINISTIC MODEL OUTPUT
>
>DETER DET21←ML21 WRK(1)
>PLOT WRK(2) DET21 " DIAGRAM 12
>
>"        COMPUTE THE NOISE SPECTRUM
>
>CASP NS21←ML21
>PLLOG NS21 " DIAGRAM 13
>
```


PLOT HP (BOX(1) BOX(2) " DIAGRAM 1
3.00E+1
2.00E+1
1.00E+1
0.00E+0
SAMPLES
0.00E+0
5.00E+1
1.00E+2
1.50E+2
2.00E+2
2.50E+2


PLOT ARR(2) " DIAGRAM 2
3.00E+1
2.00E+1
1.00E+1
0.00E+0
SAMPLES
0.00E+0
5.00E+1
1.00E+2
1.50E+2
2.00E+2
2.50E+2

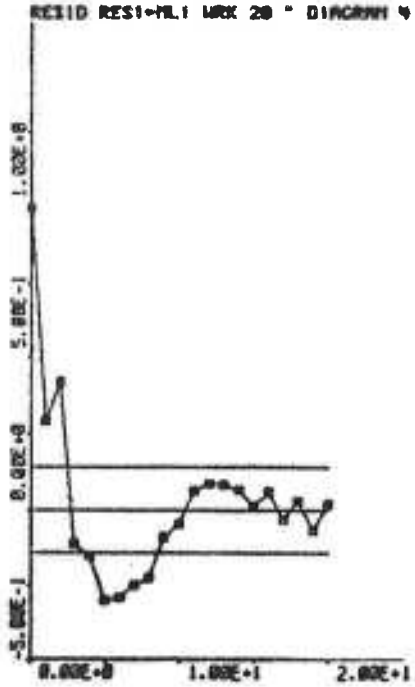

PLOT ARR(2) " DIAGRAM 3
2.00E+1
1.00E+1
0.00E+0
-1.00E+1
SAMPLES
0.00E+0
5.00E+1
1.00E+2
1.50E+2
2.00E+2
2.50E+2

```
STARTING VALUES GIVE:

LOSS FUNCTION:    4.701473E+03
LAMBDA:           6.856729E+00   +- 3.428365E-01

CONVERGENCE (DV/V< 1.E-06)
**************************

FINAL ESTIMATION
****************

A 1     -8.741825E-01 +-  3.397056E-02

B 1      3.928708E-01 +-  1.218812E-01

C 1      6.218354E-01 +-  4.705999E-02

LOSS FUNCTION:    4.253136E+02
LAMBDA:           2.062313E+00   +- 1.031157E-01

GRADIENT OF V

-2.305594E-05   2.123712E-05   3.965354E-04

SECOND DERIVATIVE MATRIX

 3.800016E+03   2.366666E+00  -4.738685E+02

 2.366666E+00   3.265586E+02   2.966208E+02

-4.738685E+02   2.966208E+02   2.249519E+03

INVERSE OF SECOND DERIVATIVE MATRIX

 2.713290E-04  -6.121458E-05   6.522807E-05

-6.121458E-05   3.492722E-03  -4.734441E-04

 6.522807E-05  -4.734441E-04   5.207081E-04

EIGENVALUES OF VIT

 3.935082E+03   2.160729E+03   2.802826E+02
```

```
STARTING VALUES GIVE:

LOSS FUNCTION:    4.701473E+03
LAMBDA:           6.856729E+00   +- 3.428365E-01

CONVERGENCE (DV/V< 1.E-06)
**************************

FINAL ESTIMATION
****************

A 1     -1.500826E+00 +-  3.923150E-02
A 2      7.061397E-01 +-  3.880084E-02


B 1      9.726903E-01 +-  7.066189E-02
B 2      5.793375E-01 +-  7.211526E-02

C 1     -2.844563E-02 +-  5.940176E-02
C 2      5.864898E-01 +-  6.812665E-02

LOSS FUNCTION:    1.247318E+02
LAMBDA:           1.116834E+00   +- 5.584170E-02
```

```
STARTING VALUES GIVE:

LOSS FUNCTION:    4.701473E+03
LAMBDA:           6.856729E+00   +- 3.428365E-01

CONVERGENCE (DV/V< 1.E-06)
**************************

FINAL ESTIMATION
****************

A 1     -7.478074E-01 +-  2.156084E-01
A 2     -4.193453E-01 +-  3.205839E-01
A 3      5.274715E-01 +-  1.549412E-01

B 1      9.549795E-01 +-  7.543264E-02
B 2      1.308100E+00 +-  2.228025E-01
B 3      4.205996E-01 +-  1.551661E-01

C 1      7.502245E-01 +-  2.084066E-01
C 2      5.705073E-01 +-  8.943689E-02
C 3      4.776322E-01 +-  1.255441E-01

LOSS FUNCTION:    1.242821E+02
LAMBDA:           1.114819E+00   +- 5.574095E-02
```

RESID RES1+ML1 WRK 20 " DIAGRAM 4




NUMBER OF CHANGES OF SIGN OF THE RESIDUALS = 73

5 PERCENT TOLERANCE LINITS
86 113

TEST OF INDEPENDENCE OF THE RESIDUALS

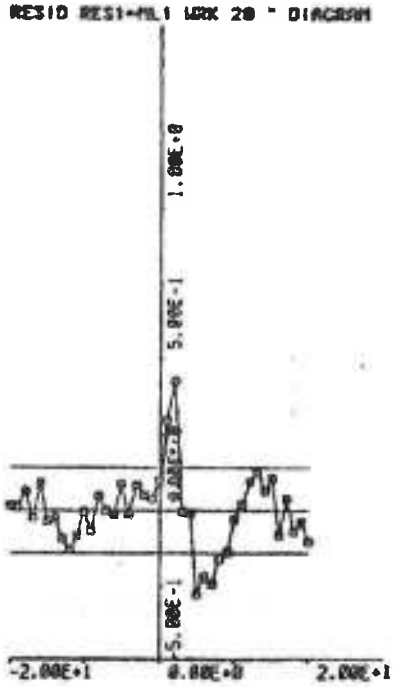
E(RES(T)*RES(T+TAU)) FOR TAU=1, 6

TEST QUANTITY 59.081
DEGREES OF FREEDOM 6

TEST OF NORMALITY

TEST QUANTITY 8.3059
DEGREES OF FREEDOM 17

RESID RES1+ML1 WRK 20 " DIAGRAM 5



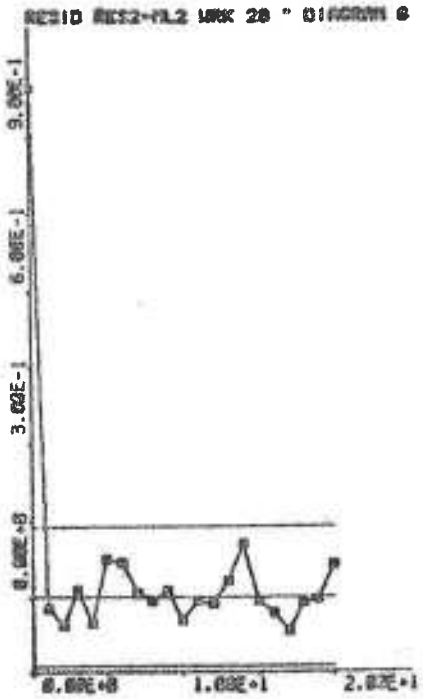

TEST OF INDEPENDENCE BETWEEN RESIDUALS AND INPUT 1

E(RES(T)*U(T+TAU)) FOR TAU= 3, 7

TEST QUANTITY 38.188
DEGREES OF FREEDOM 5

E(RES(T)*U(T+TAU)) FOR TAU=-4, 0

TEST QUANTITY 3.3898
DEGREES OF FREEDOM 5




NUMBER OF CHANGES OF SIGN OF THE RESIDUALS = 86

5 PERCENT TOLERANCE LIMITS
86 113

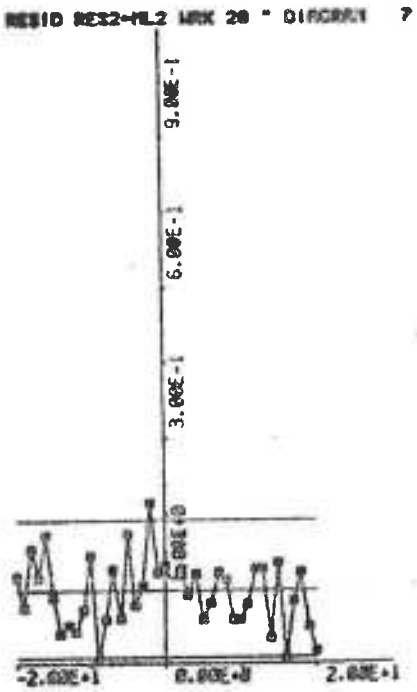
TEST OF INDEPENDENCE OF THE RESIDUALS

E(RES(T)*RES(T+TAU)) FOR TAU=1, 5

TEST QUANTITY 1.3186
DEGREES OF FREEDOM 5

TEST OF NORMALITY

TEST QUANTITY 11.809
DEGREES OF FREEDOM 17



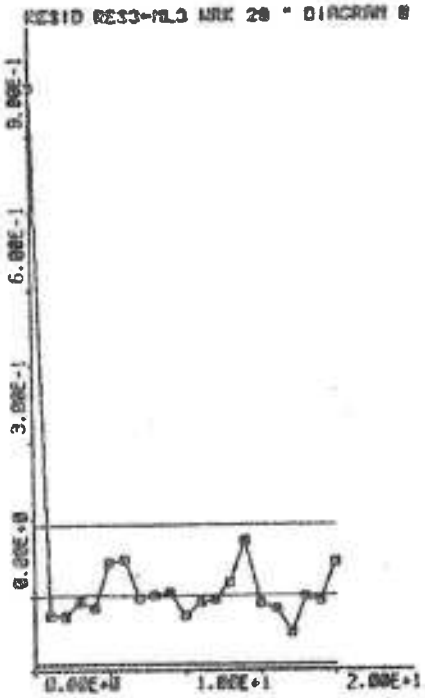

TEST OF INDEPENDENCE BETWEEN RESIDUALS AND INPUT 1

E(RES(T)*U(T+TAU)) FOR TAU= 4, 8

TEST QUANTITY 1.4712
DEGREES OF FREEDOM 5

E(RES(T)*U(T+TAU)) FOR TAU=-4, 0

TEST QUANTITY 9.6388
DEGREES OF FREEDOM 5




NUMBER OF CHANGES OF SIGN OF THE RESIDUALS = 85

5 PERCENT TOLERANCE LIMITS
85 113

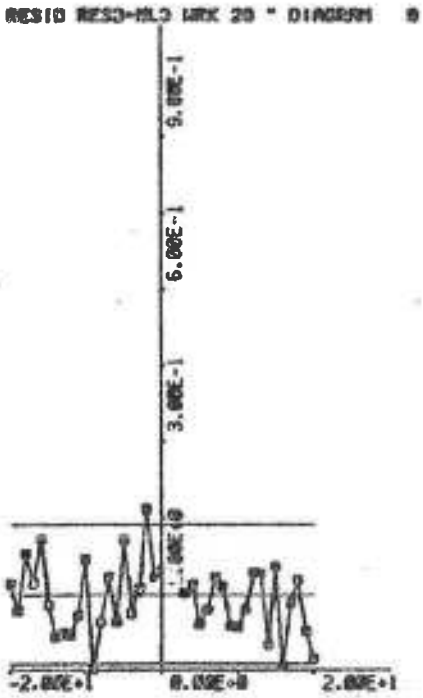
TEST OF INDEPENDENCE OF THE RESIDUALS

E(RES(T)*RES(T+TAU)) FOR TAU=1, 5

TEST QUANTITY 0.82930
DEGREES OF FREEDOM 5

TEST OF NORMALITY

TEST QUANTITY 20.496
DEGREES OF FREEDOM 17




TEST OF INDEPENDENCE BETWEEN RESIDUALS AND INPUT 1

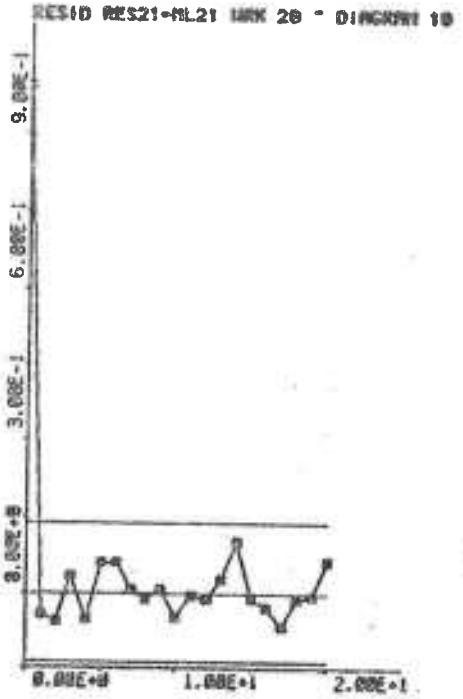
E(RES(T)*U(T+TAU)) FOR TAU= 5, 9

TEST QUANTITY 2.1912
DEGREES OF FREEDOM 5

E(RES(T)*U(T+TAU)) FOR TAU=-4, 0

TEST QUANTITY 9.0848
DEGREES OF FREEDOM 5

```
STARTING VALUES GIVE:

LOSS FUNCTION:    4.701473E+03
LAMBDA:           6.856729E+00   +- 3.428365E-01


NO SMALLER LOSS FUNCTION FOUND EVEN IF MAX RELATIVE COEFF. CORRECTION =  1.E-04
*****************************************************************************

A 1     -1.493938E+00 +-  3.733611E-02
A 2      6.992500E-01 +-  3.690687E-02

B 1      9.727951E-01 +-  7.048055E-02
B 2      5.823359E-01 +-  7.159472E-02

C 1      0.000000E-01
C 2      5.908598E-01 +-  6.653790E-02

LOSS FUNCTION:    1.248751E+02
LAMBDA:           1.117475E+00   +- 5.587376E-02

LOSS FUNCTION IN PREVIOUS STEP  1.248751E+02
```




NUMBER OF CHANGES OF SIGN OF THE RESIDUALS = 89

5 PERCENT TOLERANCE LIMITS
85 113

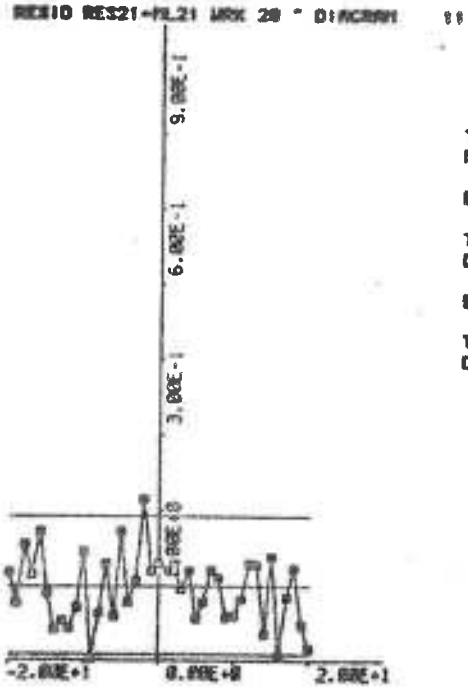
TEST OF INDEPENDENCE OF THE RESIDUALS

E(RES(T)*RES(T+TAU)) FOR TAU=1, 5

TEST QUANTITY 1.0030
DEGREES OF FREEDOM 5

TEST OF NORMALITY

TEST QUANTITY 14.016
DEGREES OF FREEDOM 17



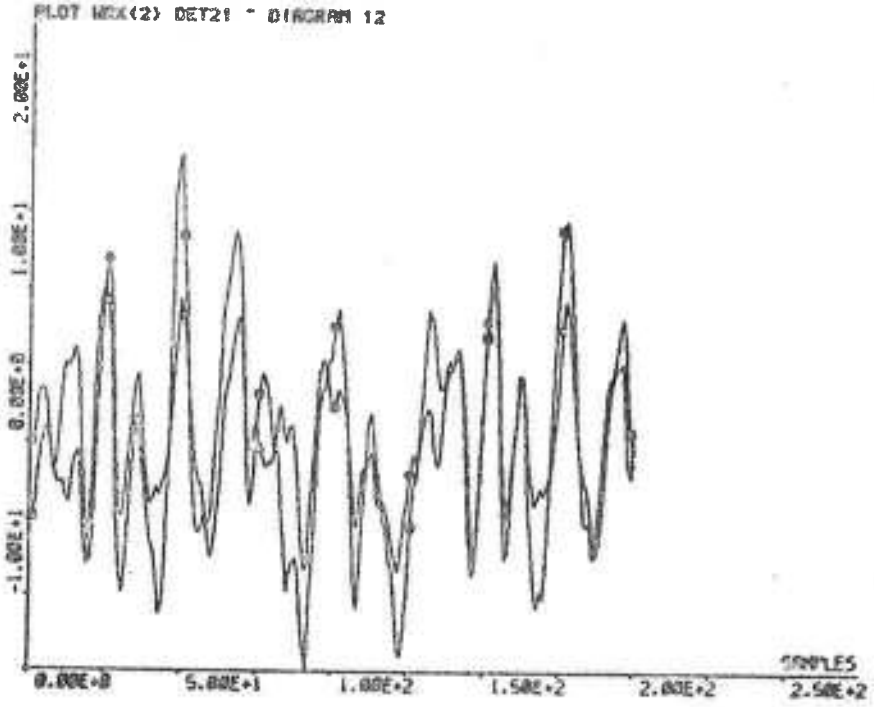

TEST OF INDEPENDENCE BETWEEN RESIDUALS AND INPUT 1

E(RES(T)*U(T+TAU)) FOR TAU= 4, 8

TEST QUANTITY 1.5020
DEGREES OF FREEDOM 5

E(RES(T)*U(T+TAU)) FOR TAU=-4, 0

TEST QUANTITY 0.7207
DEGREES OF FREEDOM 5




PLLOG HS21 - DIAGRAM 13