LUND UNIVERSITY

IDPAC User's Guide

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1973

[Link to publication](#)

Total number of authors:
3

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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 macro 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 prin-ter.

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 cons-tant.

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 para-meters.

Estimation

STAT   computes some statistical properties of a data vec-
         tor.
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 spect-
         rum between two data vectors.
ML   performs least squares and maximum likelihood esti-
         mation 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 in-
         put-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 mes-
         sages.
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 in-
         stead 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 in-
put groups) separated by a left arrow (←).

The arguments are Hollerith strings, integers, real num-
bers 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 descrip-
tions 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 imme-
diately to the right of the old ones.

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

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 prin-
ter.
FF indicates that a form feed is wanted before the text
is written.

Example

>TEXT 3 FF
□
□COMMENT
□
>

PRINT

DISP

Purpose

To print/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 da-
            ta 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 λ, the value of the loss func-
            tion, 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.
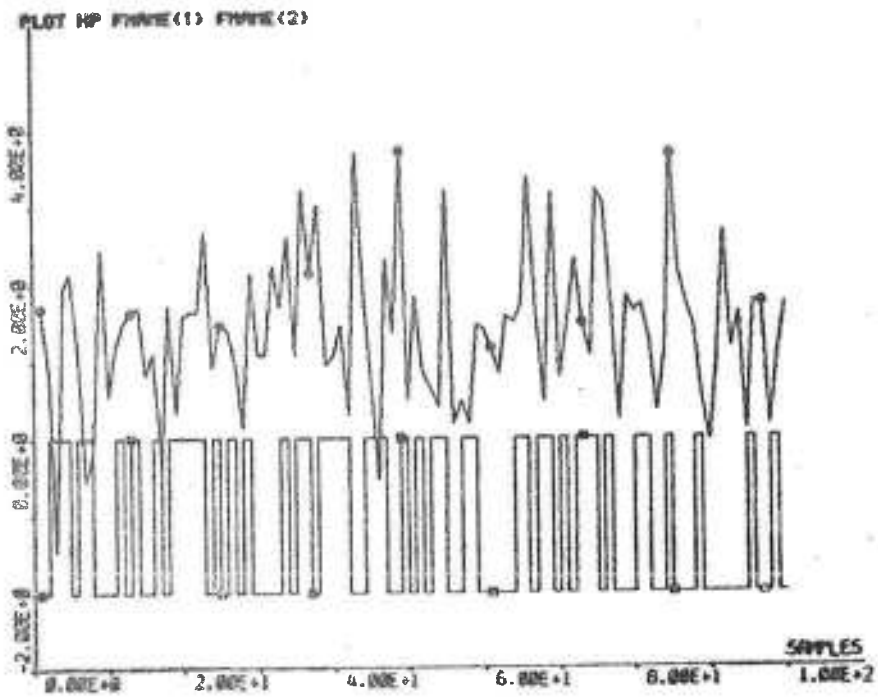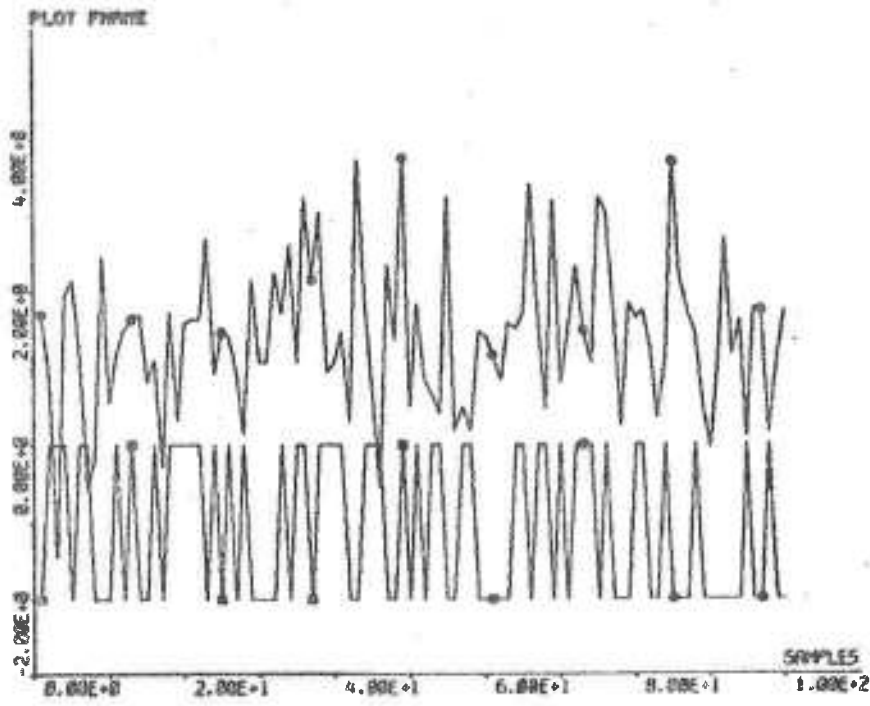
Cautions, restrictions

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 FRAME

PLOT HP FRAME(1) FRAME(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 vari-
ables 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 prog-
ram 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
```
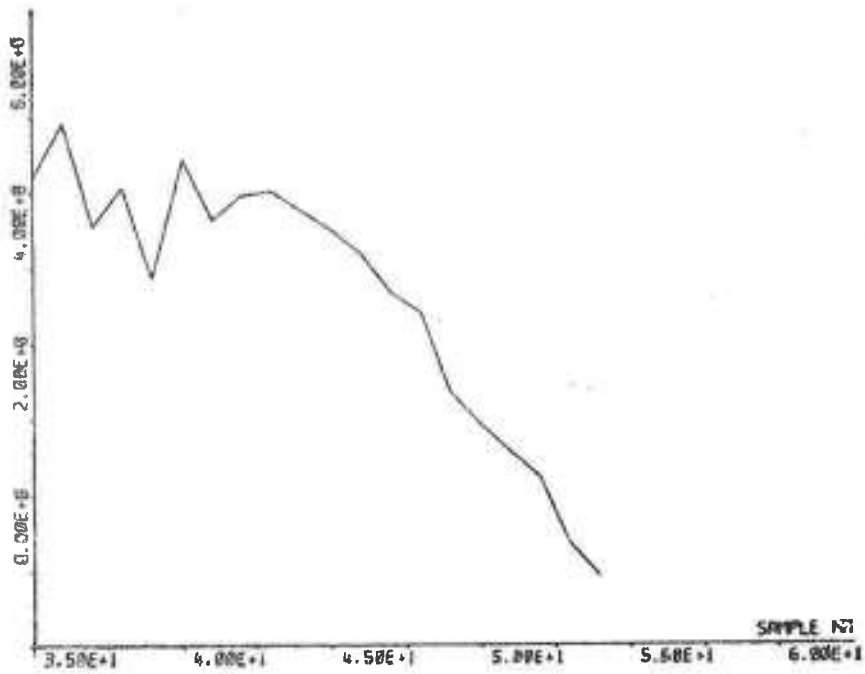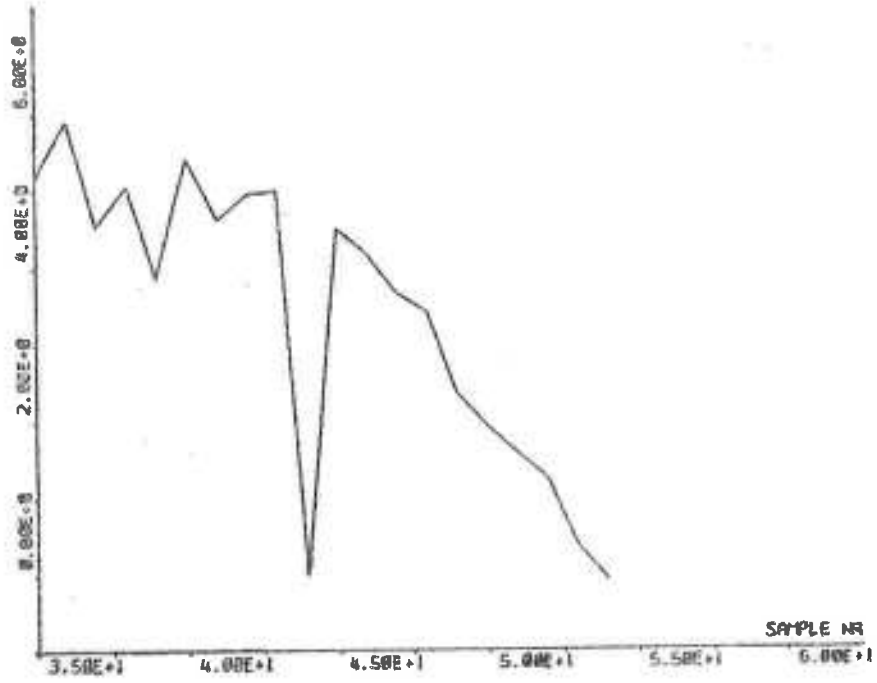
ADDC

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 re-
sult 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.     21.0000     31.0000
12.     22.0000     32.0000
13.     23.0000     33.0000
14.     24.0000     34.0000
15.     25.0000     35.0000
16.     26.0000     36.0000
17.     27.0000     37.0000
18.     28.0000     38.0000
19.     29.0000     39.0000
20.     30.0000     40.0000
```

SHORT

```
12.     22.0000     32.0000
13.     23.0000     33.0000
14.     24.0000     34.0000
15.     25.0000     35.0000
16.     26.0000     36.0000
17.     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 $(i+Kj\check{})$th element in the jth column of the input file,
where $Kj\check{}$ 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 out-
put 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.____	21.0000	31.0000
12.____	22.0000	32.000_
13.____	23.0000	33.000_
14.0_0_	24.0_00	34.000_
15.___00	25.0000	35.000_
16.0000	26.0__0	36.0000
17.0_00	27.0000	37.0000
18.____	28.0000	38.000_
19.____	29.0000	39.0000
20.__0_	30.0000	40.0000

FILE

11.____	22.0000	34.0000
12.0_0_	23.0000	35.0000
13.___0	24.0000	36.0000
14.0_00	25.0000	37.0000
15.00_0	26.0000	38.0000
16.0000	27.0000	39.0000
17.0000	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 $\in$ {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 fre-
quencies OMH and OML rad/s (high and low cut-off frequen-
cy resp.) is computed for a sample period of T s. The re-
sult 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 conti-
nuous 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 ω_i are substituted by the
'pseudo frequencies' $\nu_i = (2/T)\tan(\omega_i T/2)$. Band-pass fil-
ters 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)

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

$\quad$ 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) co-
lumn in the data file DNAM2 is computed using the autoco-
variances 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 com-
mand 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 ω is the frequency in rad/s

ΔT is the sample period in s

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

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

Cautions, restrictions

Data files with zero sample period are not accepted as in-
put 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 co-lumns 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

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

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

$$k = 0, \ldots, \begin{matrix} NOL-|IALIGN| \\ NOL' \end{matrix}$$

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

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

Then the amplitude and phase are computed from

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

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

Cautions, restrictions

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.

       0 no estimation.

PRIML 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 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 $3 \cdot$ lambda in each iteration, i.e. if $\varepsilon(t) > 3\lambda$ then $\varepsilon(t) = 3\lambda$.

      0 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.

Method

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 λ 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

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

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 esti-
mate 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: $b_1 u_1(t-1) + 1.5b_1 u_2(t-1)$
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: $a_1 y(t-1) + 3a_1 y(t-2)$
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

$$y(t) + a_1 y(t-1) + a_{12}y(t-12) + a_{13}y(t-13) =$$
$$= b_1 u(t-1) + e(t) + c_1 e(t-1)$$

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

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 λ 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:
    1.000000   -1.500000   0.700000

B 1:   (1 FOR DELAY(S))
    1.000000   0.500000

C 1:
    1.000000   -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 si-
mulated for NP points (default the number of points in the
shortest input file) using the indicated (default all) co-
lumns 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 simula-
tions of single input - single output systems with the ini-
tial 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 pa-
rameter 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 mo-
del.

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 cor-
relations between the residuals and the input(s) (if any)
are computed for up to NOL lags. Then the independence bet-
ween 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 infor-
mation 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

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

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 τ, 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 τ 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 on-
ly one A parameter and one C parameter (both equal to 1.0),
the independence and normality of a time series may be tes-
ted.

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 π/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 en-
tered.
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 en-
tered.

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 vari-
ables enables the user to alter the value of these vari-
ables.

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 in-
          verse 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 3λ in each ite-
          ration, i.e. if $\epsilon(t) > 3\lambda$ then $\epsilon(t) = 3\lambda$.

ITML   maximum number of iterations for the ML-identi-
        fier (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 poly-
                 nomial 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 frequen-
          cies 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 VIA
$A DKA 3,13,14/NON 4,5,7

$BUFFS 6

$E IDPAC

IDPAC VID


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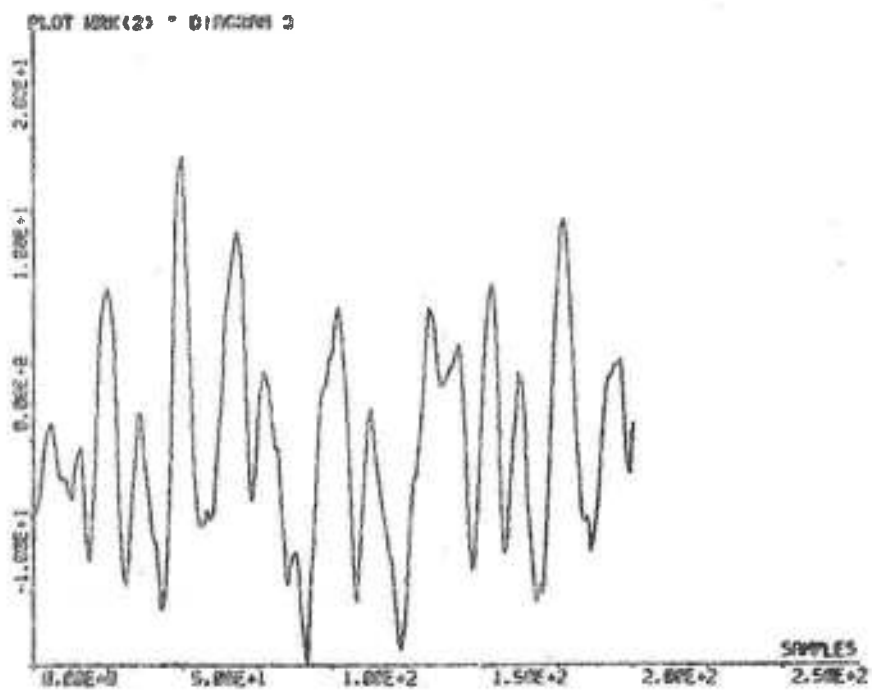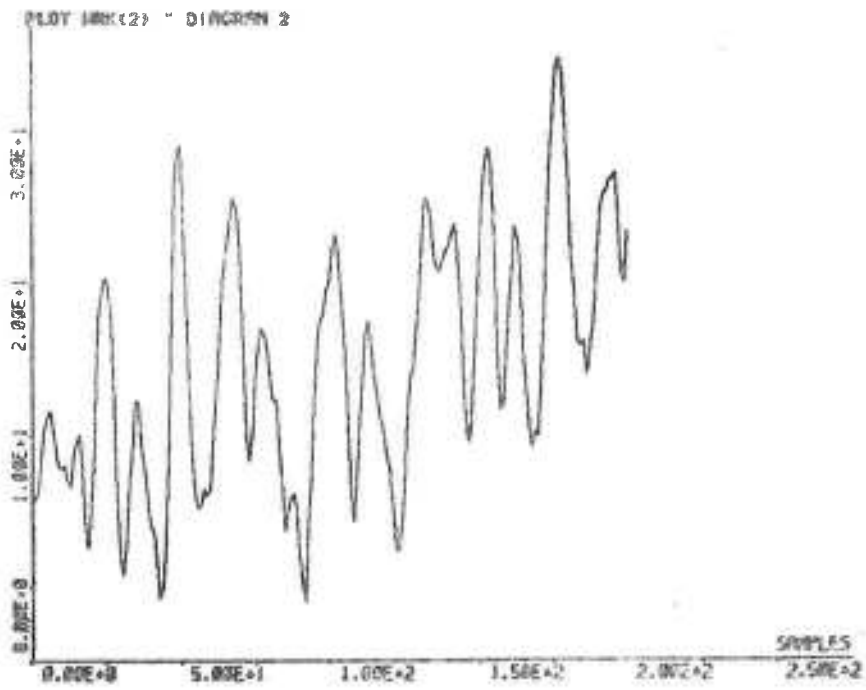
```
>
>"        COMPUTE THE DETERMINISTIC MODEL OUTPUT
>
>DETER DET21←ML21 WRK(1)
>PLOT WRK(2) DET21 " DIAGRAM 12
>
>"        COMPUTE THE NOISE SPECTRUM
>
>CASP NS21←ML21
>PLLOG NS21 " DIAGRAM 13
>
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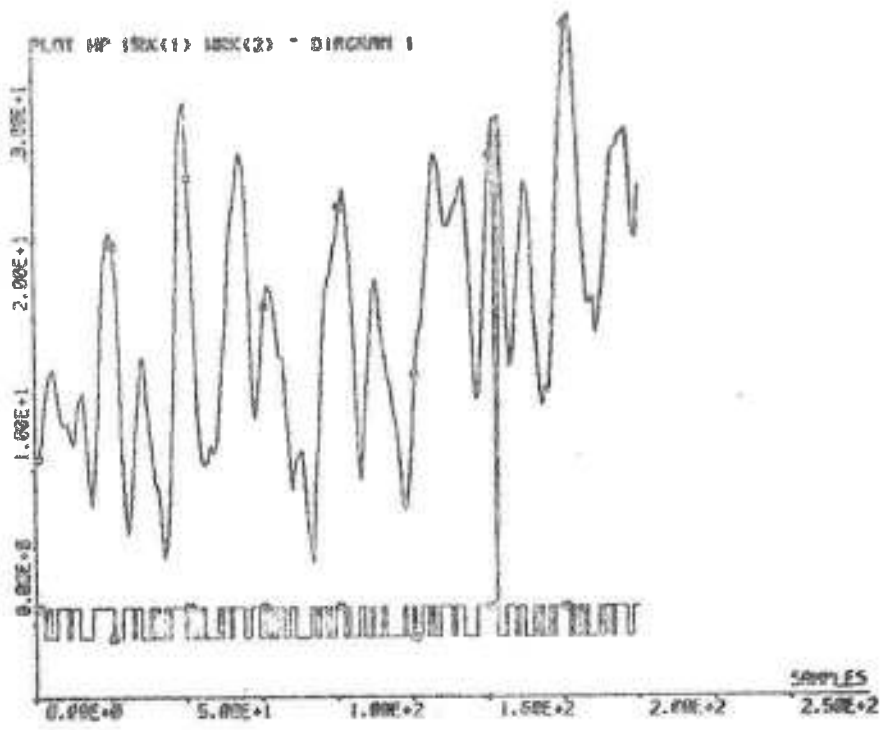
PLOT HP ISX(1) ISX(2) ~ DIAGRAM 1

PLOT WRK(2) * DIAGRAM 2

PLOT WRK(2) * DIAGRAM 3

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: 1.242621E+02
LAMBDA: 1.114819E+00   +- 5.574095E-02

RESID RES1=ML1 WRX 20 " DIAGRAM 4
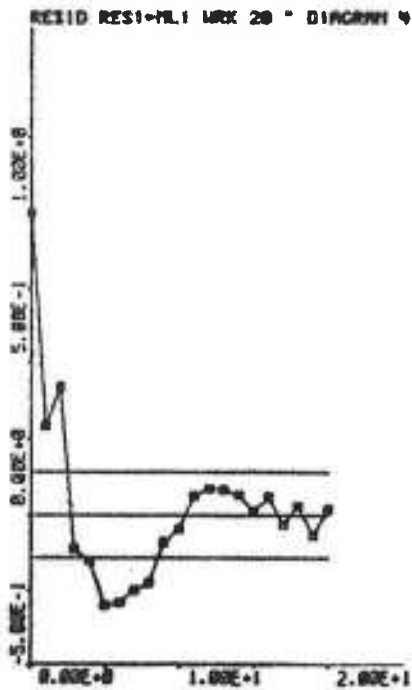
NUMBER OF CHANGES OF SIGN OF THE
RESIDUALS =   73

5 PERCENT TOLERANCE LIMITS
        86   113

TEST OF INDEPENDENCE OF THE
RESIDUALS

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

TEST QUANTITY   59.061
DEGREES OF FREEDOM 5

TEST OF NORMALITY

TEST QUANTITY   8.3559
DEGREES OF FREEDOM 17

RESID RES1=ML1 WRX 20 " DIAGRAM   5

TEST OF INDEPENDENCE BETWEEN
RESIDUALS AND INPUT 1

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

TEST QUANTITY   38.102
DEGREES OF FREEDOM 5

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

TEST QUANTITY   3.3898
DEGREES OF FREEDOM 5

RESID RES2-ML2 WRK 20 " DIAGRAM 6

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   1.3185
DEGREES OF FREEDOM 5

TEST OF NORMALITY

TEST QUANTITY   11.809
DEGREES OF FREEDOM 17
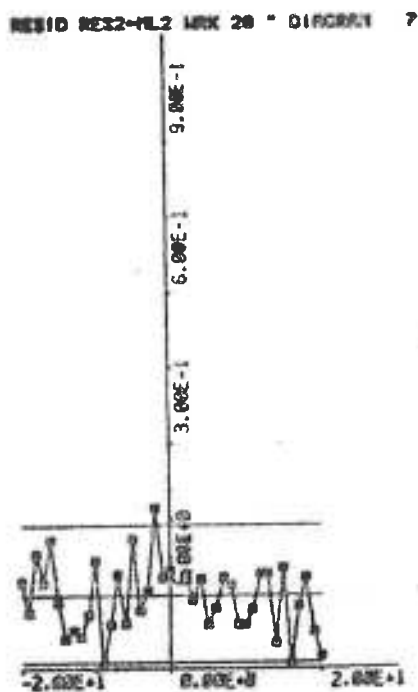
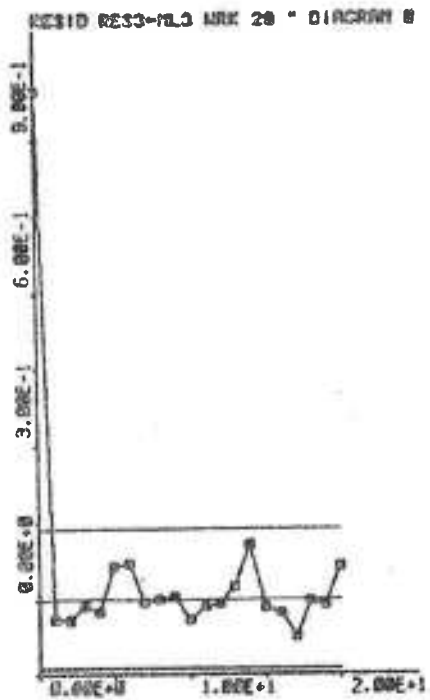RESID RES2-ML2 WRK 20 " DIAGRAM 7

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, 8

TEST QUANTITY   9.8398
DEGREES OF FREEDOM 5

RESID RES3=ML3 WRK 20 " DIAGRAM 8

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 8.82838
DEGREES OF FREEDOM 5

TEST OF NORMALITY

TEST QUANTITY 28.495
DEGREES OF FREEDOM 17

RESID RES3=ML3 WRK 20 " DIAGRAM   8
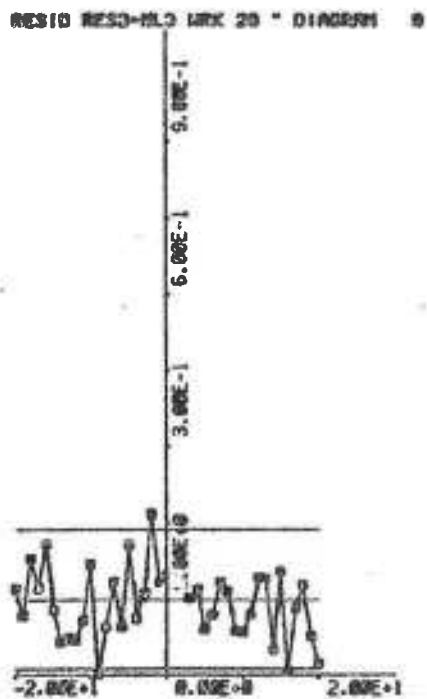
TEST OF INDEPENDENCE BETWEEN
RESIDUALS AND INPUT 1

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

TEST QUANTITY 2.1912
DEGREES OF FREEDOM 5

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

TEST QUANTITY 9.0846
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

RESID RES21-ML21 WRK 20 " DIAGRAM 10

NUMBER OF CHANGES OF SIGN OF THE
RESIDUALS =   99

5 PERCENT TOLERANCE LIMITS
      85   113

TEST OF INDEPENDENCE OF THE
RESIDUALS

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

TEST QUANTITY   1.8838
DEGREES OF FREEDOM 5

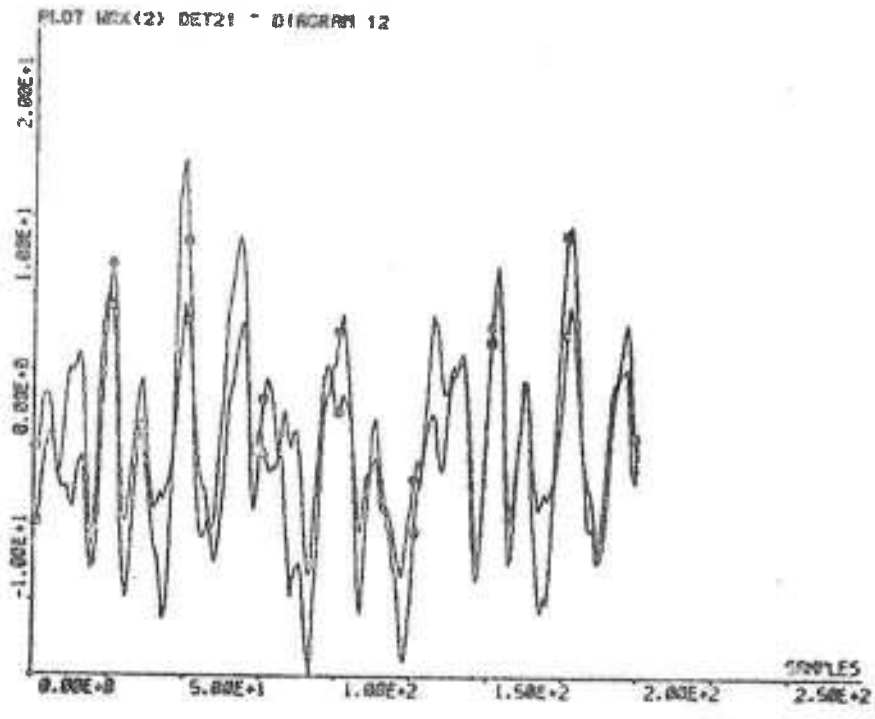TEST OF NORMALITY

TEST QUANTITY   14.816
DEGREES OF FREEDOM 17

RESID RES21-ML21 WRK 20 " DIAGRAM   11

TEST OF INDEPENDENCE BETWEEN
RESIDUALS AND INPUT 1

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

TEST QUANTITY   1.5828
DEGREES OF FREEDOM 5

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

TEST QUANTITY   8.7287
DEGREES OF FREEDOM 5

PLOT WEX(2) DET21 * DIAGRAM 12

PLLOG MS21 * DIAGRAM 13