Name	CALEX
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This program determines system parameters, such as corner periods and damping constants of analog filters or seismometers, by modeling the response of the system to an arbitrary input signal in the time domain, and fitting it to the observed output signal. The input signal and the response must be digitally recorded. The test signal may be generated by any practical means, even by operating a switch or a potentiometer by hand; it must however contain sufficient energy at frequencies of interest.

The program requires three input files in ASCII format:
- A file 'calex.par' containing numerical parameters for the inversion and start values for the   system parameters
- A file 'eing' containing the test (input) signal
- A file 'ausg' containing the output signal

The following output files are generated:

'einf ' :   a low-pass (anti-alias) filtered version of 'eing'
'ausf ' :   a low-pass filtered version of 'ausg' for direct comparison with 'synt'
'synt ' :   the synthetic output signal. If this does not fit the signal
                'ausf ' at all you have probably made a mistake in defining the system.
'rest ' :   the residual. These files have the same format as 'eing' and 'ausg'
'calex.out ' : a protocol of the inversion, identical to the printout on the screen. Its central section lists the number of the iteration, the rms residual error (normalized to the rms output signal), and the normalized values of the active parameters. The absolute value of each parameter (as given at the end of the inversion) is start value + normalized value * uncertainty.

Format of the DATA FILES

The structure of the data files is as follows:
- one header line, arbitrary (will be echoed but not evaluated)
- additional header or comment lines whose first character is %
- one line containing the number of samples, the FORTRAN format in which they are listed, and the sampling interval. These three entries must be in the FORTRAN format (i10,a20,f 10.x).
- data in the specified format

You may easily change this file structure in the source code.

Format of the PARAMETER FILE

calex.par contains five types of lines:
- a header line
- lines with a control parameter (a single number) for the inversion
- lines with a keyword defining a subsystem
- lines specifying one parameter of a subsystem
- the end line

These lines appear in the sequence: header - control parameters - keyword - system parameter(s) - keyword - system parameter(s) - … - end line

Lines beginning with a blank are considered as comments and ignored.

The control parameters (one parameter per line, flush left) are:

alias: the corner period of the numerical anti-alias filter that is part of the CALEX routine. Must be at least 4-5 times larger than the sampling interval. This filter is required because the bandwidth of the simulated system must be smaller than the Nyquist bandwidth. The program determines the order (steepness) of the filter so that the Nyquist condition is satisfied.

m: the number of active (unknown) parameters in the inversion. The minimum set of parameters comprises a gain factor and a constant delay, plus the unknown corner periods and damping constants.

m0:   number of additional powers of the Laplace variable s in the nominator of the transfer function, equivalent to forming the m0-th time derivative of the signal. m0 may also be < 0 when the signal is integrated in the system.

ml: number of first-order high-pass or low-pass subsystems in the transfer function. A corner period must subsequently be specified for each of these.

m2:   number of second-order high-pass, low-pass or band-pass subsystems in the transfer function. A corner period and a damping constant (fraction of critical damping) must subsequently be specified for each of these.

maxit: the maximum number of iterations in the conjugate-gradient optimization procedure

qac,
finac: the iteration stops when the improvement in the rms misfit in one step becomes less than qac and the normalized parameters change by less than finac.

nsl,
ns2:   the input and output signals are analyzed in a time window from sample nsl to sample ns2, the values 0 mean first resp.last sample.

The system parameters are specified as follows: a line with
- nam val unc (three entries separated by spaces) where nam is an arbitrary name (three characters) that appears in the printout ;
- val is the initial value of an active parameter, resp. the fixed value of a passive

parameter;
- unc is the estimated uncertainty of an active parameter, resp. zero for a passive parameter.

Two system parameters are always required:
- amp   a gain factor
- del   a time delay, normally used to describe the delay of low-pass filters in the system that are not explicitly specified. Any skew in the sampling of the digitizer channels, or other differential delays, may also be included here.

The del parameter can be replaced by the sub parameter. The latter specifies a fraction of the input signal that is subtracted from the output signal. This is necessary when a geophone has no separate calibration coil and is calibrated in a half-bridge. The del and sub parameters cannot be used at the same time. This is the only case where the name of a parameter matters; calex treats this parameter differently depending on its name.

The number and arrangement of the other system parameters depends on the system. Specify all first-order subsystems before all second-order subsystems. The parameter lines for each subsystem must be preceded by a line defining the type of the subsystem: lp1, hp1, 1p2, bp2, or hp2 where lp1 denotes a low-pass filter of first order, etc. Example:

```
lp2
per     30.             1.
dmp          0.707          0.01
```

for a second-order Butterworth low-pass subsystem. The damping parameter appears only in second-order subsystems. The names must not be blank.

A sample parameter file follows. The seismometer is described as a band-pass filter (which it actually is when excited over the calibration coil). Alternatively it could be described as a low-pass filter with an additional differentiation (m0=1), or as a high-pass filter with an additional integration (m0= -1). The gain factor amp would be different in these three cases.

Example 1: Calibration of the broadband (20 sec) seismometer STS-1 No. 14

```
1       alias
4       m
0       m0
0       ml
1       m2
48      maxit
le-5    qac
le-2    finac
1   ns1
6812 ns2
amp    1.3             0.10
del       0.01          0.01
bp2
```

```
per    20.            1.
dmp    0.7            0.1
end
```

This file is separately supplied as 'calex.par1'. The data files ‚eing1' and 'ausgl' can be analyzed using this parameter file; copy these three files onto 'calex.par', 'eing' and 'ausg', respectively. The test signal was a sinusoidal sweep. Note that the output signal contains a disturbance after 52 seconds caused by a person entering the room. The disturbance is clearly visible in the residual.

The files 'calex.par2', 'eing2' and 'ausg2' describe the calibration of a 10 Hz geophone in a half-bridge. The 'del' parameter is replaced by the 'sub' parameter in this parameter file.

Example 2: Calibration of the 10 Hz geophone No. 10_Q in a half-bridge

```
0.05    alias
4       m
0       mO
0       ml
1       m2
60      maxit
1e-5    qac
1e-3    finac
201     nsl
0       ns2
amp  1.2            0.2
sub  0.5            0.2
bp2
per  0.1             0.01
dmp  0.6             0.1
end
```

These are examples for simple systems. You may include any (reasonable) number of additional subsystems such as analog filters in the analysis, by simply appending their definition and their parameters to the calex.par file. The parameters m, ml and m2 must be specified accordingly. The program will check the number of active parameters (defined by nonzero uncertainty) and the number of subsystems of first and second order and complain if there is a discrepancy. In the unlikely event that you want to use more than 24 system parameters, more than 12 active parameters, or more than 12 000 data samples, you must change the array dimensions in the source code.

Download

- The source code and test data are available by anonymous ftp from:
  ftp.geophys.uni-stuttgart.de/pub/ew/calex

- MS-DOS executables and libraries are found in …/ew/cutables.dos