SECTION I

INTRODUCTION

The DISPRO software system is a collection of 16 .EXE modules, 6 .TXT files, and 1 .DTA file. The supervisory module has the name DISPRO25.EXE; it performs initialization, processes menu selections, and gets data file names when needed for a selected operation. When a menu selection is made control is passed to the proper processing module. When the activity of the selected processing module is finished, control passes back to the DISPRO supervisor (i.e., to the supervisory module DISPRO25.EXE). When control resides in the DISPRO supervisor then you, the user, will be said to be at the "DISPRO command level".

The processing modules form five groups:

	Menu Item
• IIR and FIR filter design	*Design*
• Processing of filter coefficients	*Coefficients*
• Computation and plotting of frequency response data	*Frequency-Response*
• Evaluation, simulation, and plotting of time-domain behavior	*Time-Response*
• FFT-based spectral analysis and plotting	*Spectrum*

Each of these groups (plus *Help*) is chosen through the main menu selection process. The items on the pull-down menu will provide access to the appropriate processing module.

1.1 Operating Principles

The DISPRO25.EXE supervisory module does no computation; instead, it tests the environment, prompts for a file name if one is required by the menu selection, checks for the file existence, and then transfers control to the proper module.

DISPRO's modular structure makes minimum demands on computer memory. If large amounts of data must be transferred from one module to another it is done through disk files; this not only minimizes memory demands but also preserves the results of a design session in case of early termination—either by choice or inadvertently.

You will usually start by designing a filter. This is a completely interactive process, with you providing all input to the program through the keyboard. The resulting filter specifications, and the coefficients calculated by the design module, will be written to a filter data file. In DISPRO this is a mandatory step because all additional processing will reference this file. A default file name is created and indexed automatically; you can override this default naming process and assign the file any name you choose. Each data diskette used in drive A: or B:, or the actual subdirectory used on drive C:, D:, or E:, will have a DISPRO-created index file named FILES.INX which catalogs only the automatically-named-and-created filter data files. DISPRO must create FILES.INX, so do not use FILES.INX as the name of any of your files. The automatically-chosen names of the filter data files will be unique on each data diskette, or within each subdirectory. All DISPRO-created filter data files are in ASCII format with each section of data clearly labelled; any data file can thus be viewed using the DOS command "type filename", or any word processor or editor.

The coefficients calculated by the filter design module are written to the filter data file in floating point precision. Rounding down to a shorter word length, as is required when the filter is to be implemented using fixed-point, or integer arithmetic, is done in the module ROUNDCOF. The coefficients can be quantized to any wordlength between 4 and 24 bits. The quantized coefficients can be appended to the filter data file, and also printed in decimal integer and/or 2's-complement hex format.

The frequency-domain and time-domain properties of a filter may be evaluated for any wordlength. When the floating-point precision coefficients are used for frequency response computation then the purpose is to document the behavior of the filter as described by its frequency domain specifications. For IIR filters, the floating-point precision frequency response is exactly what you specified; for FIR filters, because the specification process is not exact, computing the floating-point precision frequency response is a necessary step in evaluating the filter design. Computation of a frequency response using quantized coefficients serves to illustrate the degree of sensitivity of the filter performance to the use of finite precision coefficients — i.e., the degree to which the poles of IIR filters, and the zeros of IIR and FIR filters, are modified by the finite-precision coefficient values.

Similar statements can be made about the time domain response. Using the WAVEGEN module you can establish an excitation file containing a sampled test signal. The response of any filter operating in a specified finite-wordlength integer arithmetic can then be determined in the TIMERESP module using that test signal as input. In DISPRO the time-response of the filter is determined by an actual simulation of filter operation in 2's-complement arithmetic.

The frequency and time response data may be plotted on the screen, and a hardcopy of the plot may be created on the line printer. A broad range of scale values may be selected for time, frequency, and amplitude so that the response data may be viewed globally or in close-up detail.

DISPRO provides spectrum analysis capabilities of a general nature. Time domain data may be entered through the keyboard, read from a user-created disk file, or obtained from a filter data file. For example, the spectra of the input and output signals involved in a filter time-domain response evaluation may be determined with the spectral analysis modules, and plotted on the screen or printer.

To conclude this brief introduction to DISPRO v2.5 it is instructive to look at the steps in a complete design and evaluation process for an Elliptic IIR filter. When each of the designated modules is invoked there will be an additional set of subcommands, menus, or prompts.

- Specification of the filter characteristics is done through an interactive dialogue using a graphical representation of the filter shape. A filter data file is created, and the filter specifications and coefficients are written to it. Specifications, floating-point coefficients, and pole-zero values are available for display or output to the printer (pole-zero plots can also be displayed or printed).

- Frequency responses may be computed and plotted for the filter using any coefficient wordlength. Response data may also be written to the filter data file for later plotting, or selected values may be displayed on the screen and/or printed on the line printer. Plotting of frequency response data uses both automatic and user-controlled scales. At the user's option any screen plot can be transferred to the printer.

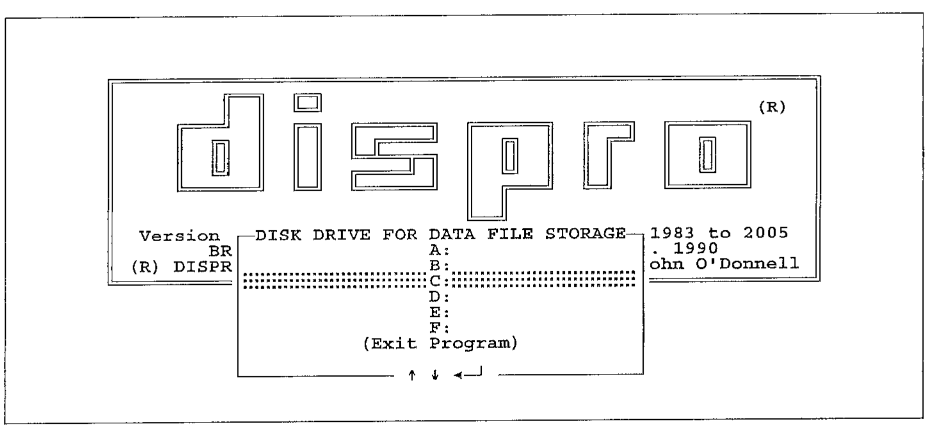
- The time response of the filter can be evaluated in the actual arithmetic of the target processor. Computation of the impulse response allows evaluation of the effects of roundoff noise on stopbands. Processing a set of data samples through the filter will show the actual frequency discrimination behavior in finite-precision arithmetic. The time response module allows much flexibility in evaluating the filter response. Time response samples may be written to the filter data file for analysis with the FFT modules.

- The spectrum of the output samples computed by the time response module is evaluated using the *Spectrum* menu selection. Because the underlying algorithm is the FFT, the number of time samples processed will be a power of 2. Data windowing is available. The spectrum analysis module contains all facilities for printing and plotting of spectral data.

As can be seen from this brief discussion, DISPRO v2.5 provides all of the tools needed for digital filter design and performance evaluation. The tools are selected at the DISPRO command level, and may be used in any logical sequence. Filter data files are automatically created, and their contents processed, without the need for user intervention. These filter data files are in ASCII format, with a documented structure, so that selected data from these files may be processed by special-purpose user-created BASIC or C programs. Such programs could represent other signal-processing functions of the system within which the filter is to operate. In addition, the analysis facilities of DISPRO may be applied to filter data files that are created by the user with coefficients not calculated by DISPRO. Utility programs that can be user-modified are listed and described in Section 5 of this manual; source code for these programs is on the diskette accompanying this manual.

1.2 Starting Up DISPRO

You should already have created a hard disk directory and copied the contents of the distribution diskettes to that directory. Let's assume that you have created a directory named *FILTER* for the DISPRO modules, and a subdirectory *DATA* for the filter design files which will be created by DISPRO. After you give the DOS command *CD FILTER* you start the program by typing *DISPRO25*. The first screen that appears is



where, on the color display, a green highlight bar can be moved by the cursor keys to one of the indicated disk drive designators. When a drive is selected, by positioning the highlight bar and striking the *Enter* key, the next screen is

```
                                                              (R)
Version 2.5 Copyright(C) Dr. John O'Donnell 1983 to 2005
      BRT71EFR.EXE Copyright(C) Microsoft Corp. 1990
 (R) DISPRO is a Registered Trademark of Dr. John O'Donnell

Specify directory for data file storage on drive C:
    Directory ? filter\data
[Strike ENTER to use current directory...Esc to Cancel];
[  A blank entry will select default directory on indicated drive.]
[  Include drive letter in pathname to change to another drive.]
```

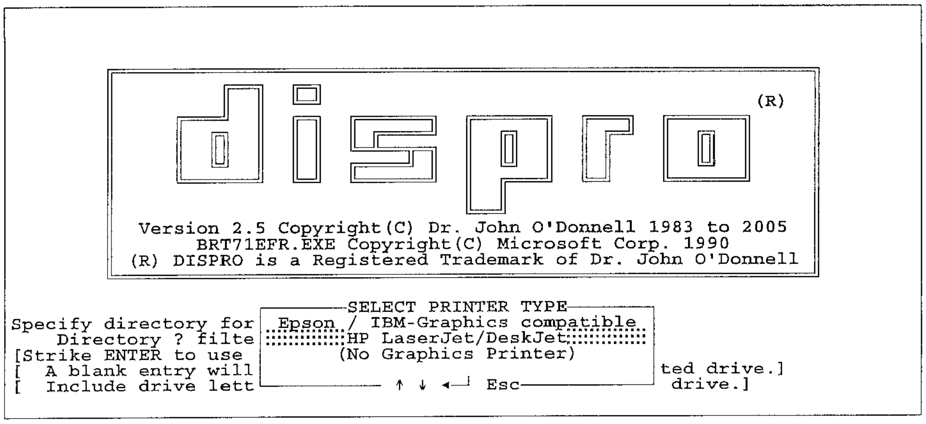
where we have selected drive D: for data file storage. The directory is the subdirectory that has been created for the filter data files, *FILTER\DATA*.

If this is the first time that the directory C:\FILTER\DATA has been used for DISPRO data file storage then the next two screens will be

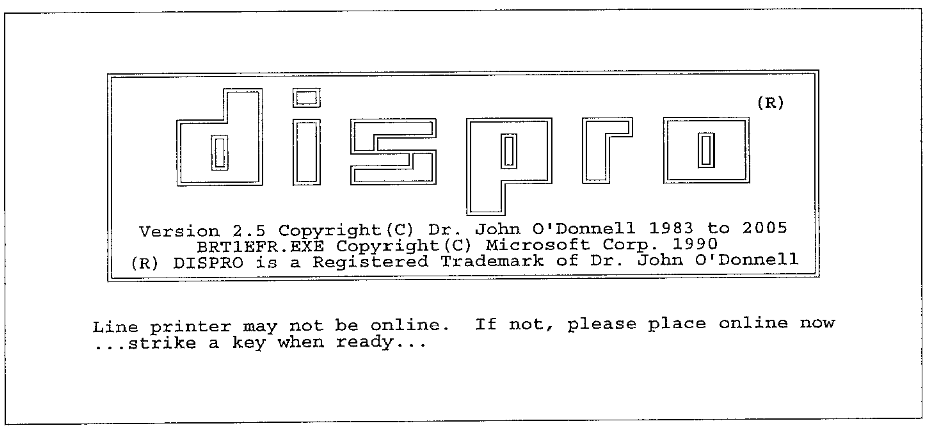
```
                                                              (R)
Version 2.5 Copyright(C) Dr. John O'Donnell 1983 to 2005
      BRT71EFR.EXE Copyright(C) Microsoft Corp. 1990
 (R) DISPRO is a Registered Trademark of Dr. John O'Donnell
        Creating FILES.INX on path E:\DATA\
        ...strike a key when ready...(Esc to cancel)...

Specify directory for data file storage on drive C:
    Directory ? filter\data
[Strike ENTER to use current directory...Esc to Cancel];
[  A blank entry will select default directory on indicated drive.]
[  Include drive letter in pathname to change to another drive.]
```

```
                                                              (R)
Version 2.5 Copyright(C) Dr. John O'Donnell 1983 to 2005
      BRT71EFR.EXE Copyright(C) Microsoft Corp. 1990
 (R) DISPRO is a Registered Trademark of Dr. John O'Donnell
        Using FILES.INX on path C:\DATA\
        ...strike a key when ready...(Esc to cancel)...

Specify directory for data file storage on drive C:
    Directory ? filter\data
[Strike ENTER to use current directory...Esc to Cancel];
[  A blank entry will select default directory on indicated drive.]
[  Include drive letter in pathname to change to another drive.]
```

because DISPRO failed to find a file named *FILES.INX* in the subdirectory, and will now create it. After the file FILES.INX has been created you will see the following screen.



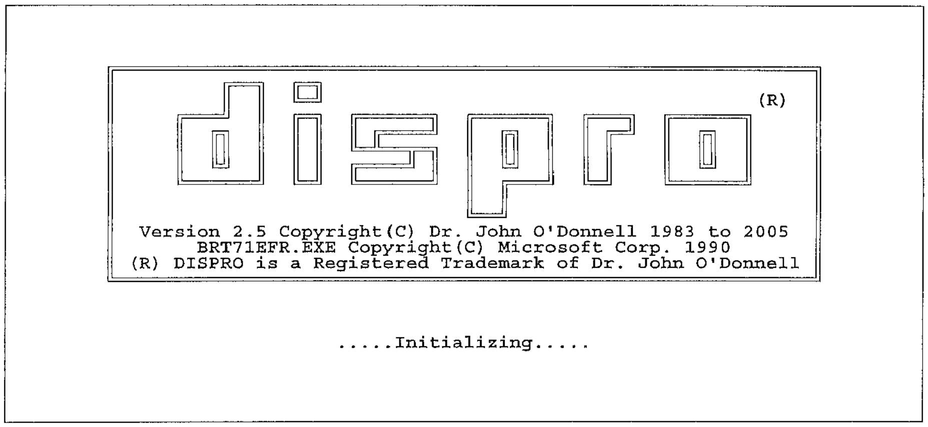
DISPRO supports graphics output on the two categories of printers indicated. The printer type that you select should be connected to the LPT1: parallel port. DISPRO next tests for the printer online; this is a warning to you so that you can avoid any annoyance later when you direct output to the printer.



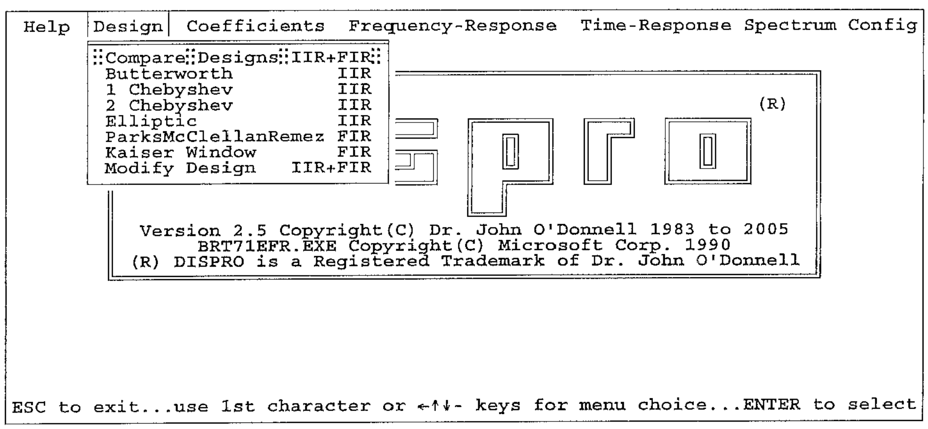
If the printer is not on line when you direct output to it, no design data would be lost because DISPRO always saves the filter specifications and coefficients to a filter data file before any printout can occur.

<u>Important</u>: After DISPRO is used for the first time there is created a "configuration file", DISPRO25.CFG, which contains your selections for the data file directory and the type of graphics printer. Thereafter, when DISPRO is started, this file will be read so that you do not have to reënter what is effectively static information. If you wish to change the drive or directory or printer choices then simply use the *Config* menu selection.

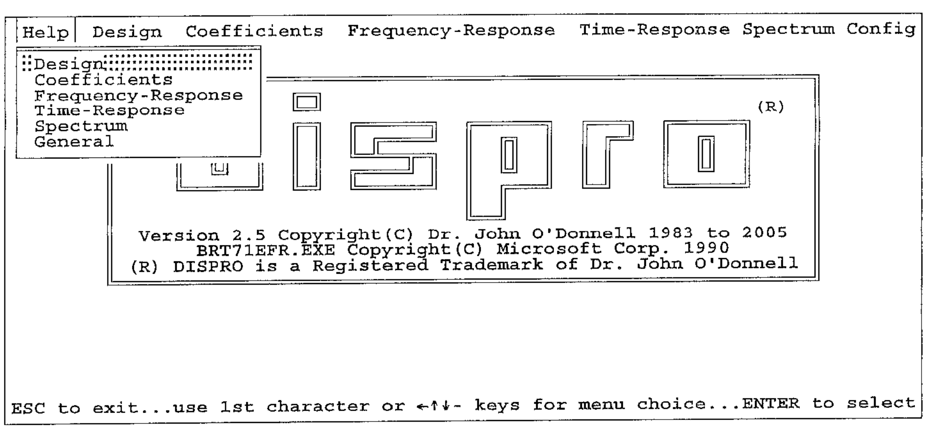
As a final step before you are ready to do a design or analysis with DISPRO you will see the screen below. The duration of this initializing process depends on the speed of your computer.



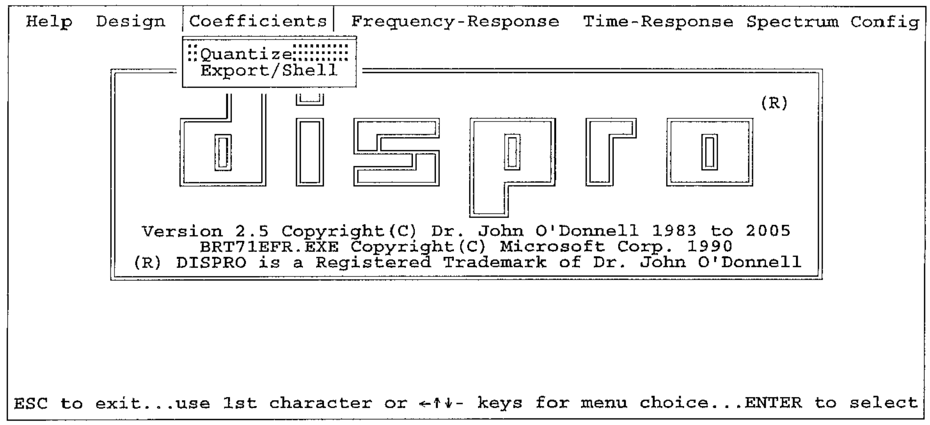
After the startup phase you will be at the *DISPRO command level*, ready to pick one of the main menu selections. When DISPRO first starts the default choice is the *Design* selection. The *Compare Designs* option lets you see the order/length for the IIR filters and the PMR FIR filter that would be required to meet your specifications; you can choose to design any one of these types. The *Kaiser Window* FIR is a special case and must be accessed directly. *Modify Design* is an option which allows you to use the specifications from any existing filter data file as the starting point for another design — the filter may be the same or a different type.



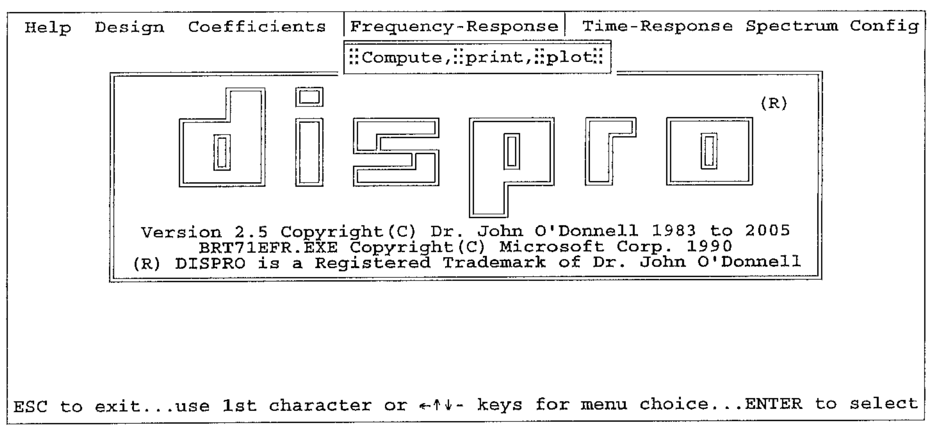
Help files can be viewed on screen; they contain useful summary information, and can minimize the need to refer to the manual for less-often used DISPRO features.



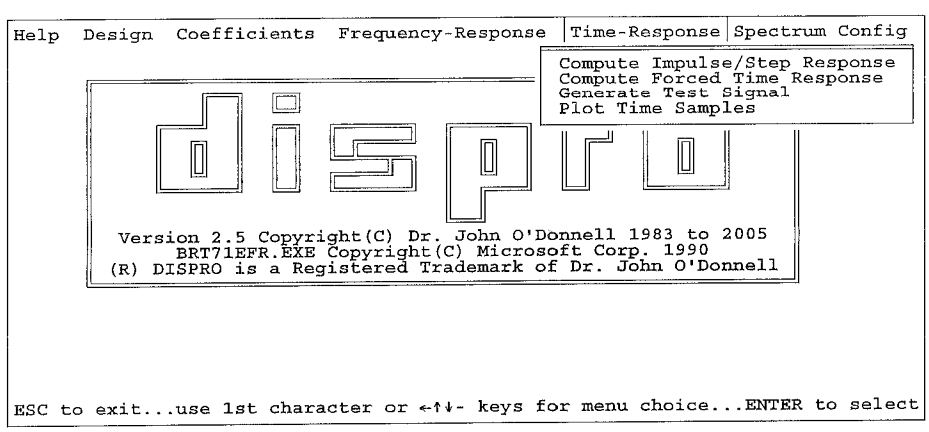
To obtain explicit values, either displayed or printed or stored in the filter data file, pick the *Quantize* option. The *EXPORT/SHELL* option serves two functions: create a code file to be used with commercially available DSP processors, and SHELL to an external program.



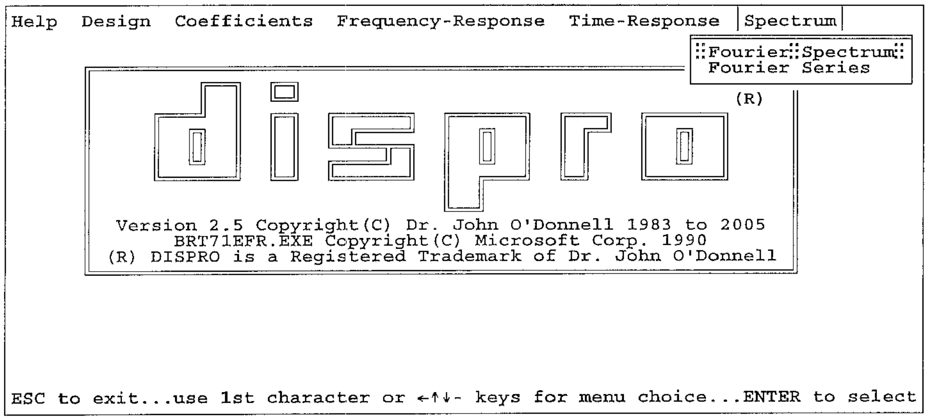
The frequency response of an existing design can be computed, printed, or plotted using this menu selection. Note that direct access to the *Frequency-Response* module is provided by the menus in the filter design modules also.



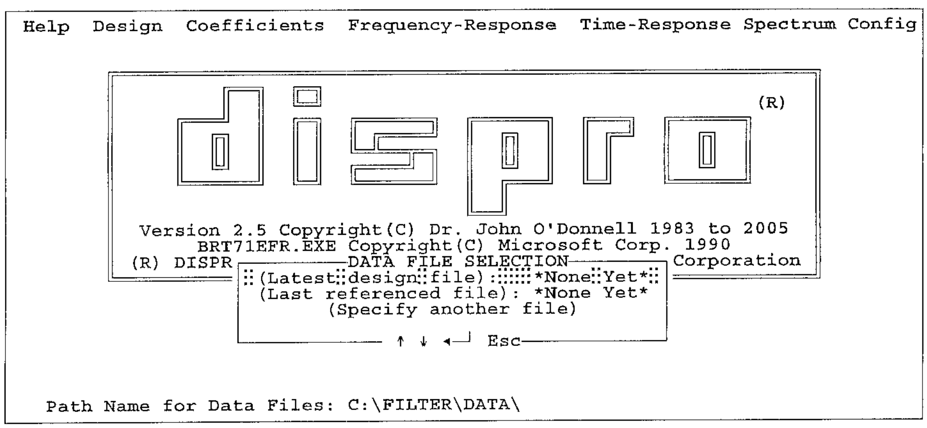
The *Time-Response* menu options are self-explanatory. Note that in order to compute a response you will have had to previously designed the filter. Also, for a forced response you must have available an excitation file with the samples of the test signal; you may create this file from your own data, or you can use the *Generate Test Signal* option. Time samples in excitation files, or time responses in filter data files, can be plotted.



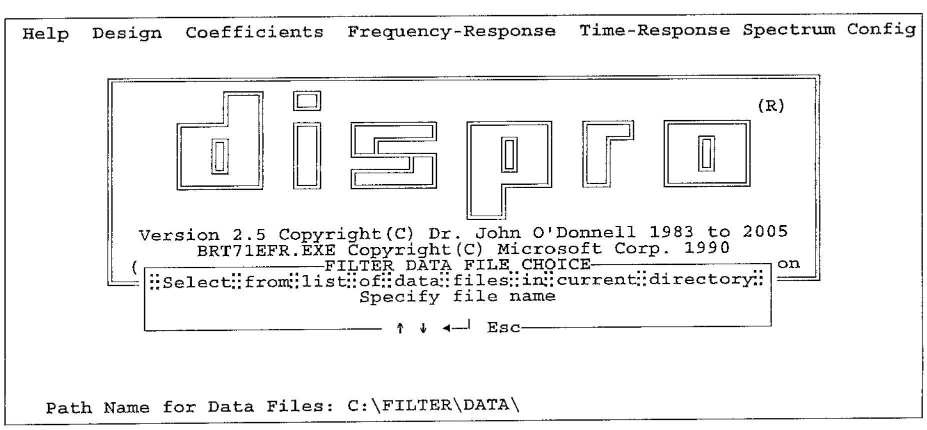
The spectrum analysis capabilities are fairly general, and are based on the use of the radix-2 FFT; allowed sizes are from 8 to 8192 real-valued time samples, giving from 4 to 4096 complex-valued positive frequency samples. Data samples can be input from the keyboard, or retrieved from a filter data or excitation file. The *Fourier Series* option should be used only for analyzing periodic waveforms (because of the special scaling which gives Fourier series coefficients).



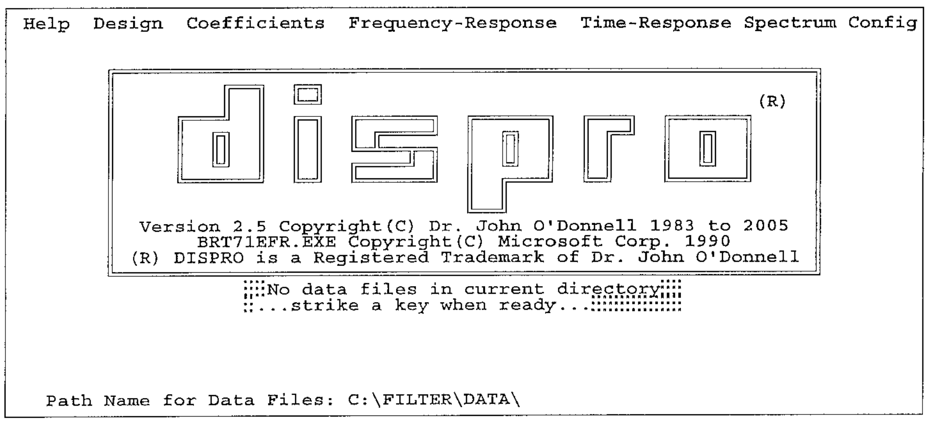
Many menu options require that one or two file names be provided. In these cases the screen will become



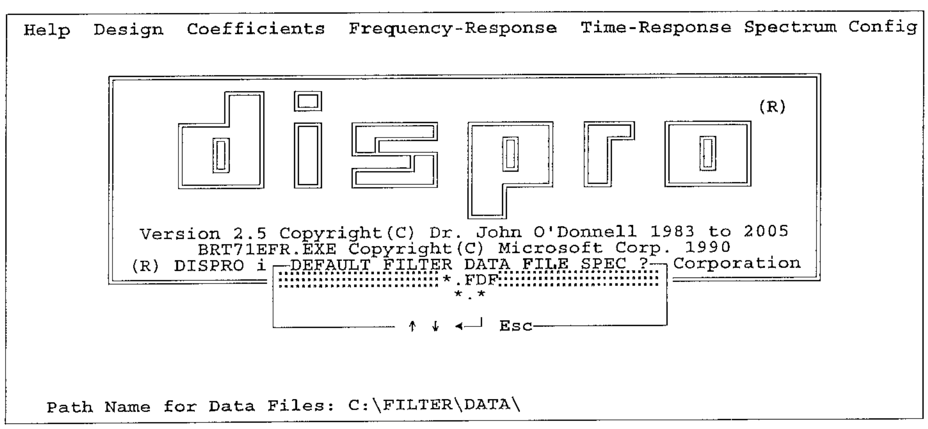
The latest design file is the filter data file just created by one of the design modules. The last referenced file may be the same design file or it may be any file with information acceptable to one of DISPRO's processing modules. If you wish to select another file then you may progress to the screen



You will generally choose to select a file from those in the current directory. Depending on the main menu selection that you have made there will appear one or more additional pop-up menus giving you more specific options for file selection. In general there are two classes of files available: filter data files with the default extension of .FDF, and excitation files with the default extension of .EXC. For spectral analysis you can also choose the keyboard as the input source. When you want to choose from the files in the current subdirectory you can specify what files are to appear in the directory list, either *.FDF, *.EXC, or *.*. If you choose *.* then DISPRO uses a mask to exclude those files with extensions which are obviously not candidate filter data or excitation files; the excluded file extensions are .EXE, .TXT, .DTA, INX, .BAS, .BAT, .COM, .DMR, .OBJ, and .CFG. If there are no valid file names you will see



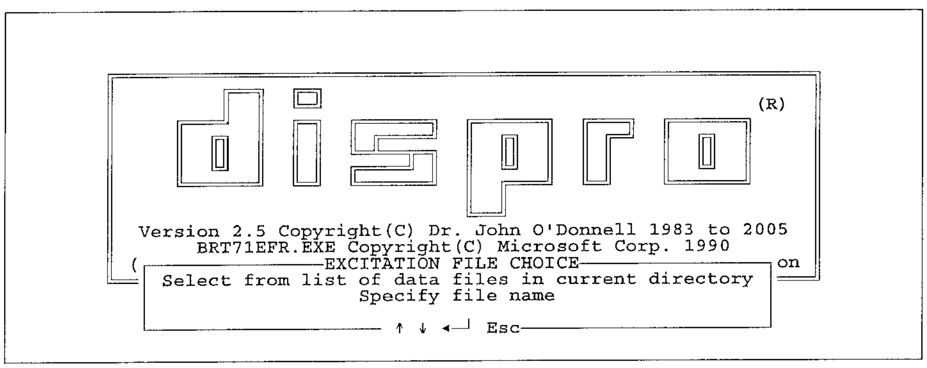
otherwise you will see a directory from which you may select your file by using the cursor keys to position the highlight bar. When a filter data file name is required you will be asked to choose the default specification used in listing the files on the current path. Because DISPRO's default filter data file name extension is .FDF this is the first choice; the alternative is *.*, with the exclusion of certain file extensions as noted above.

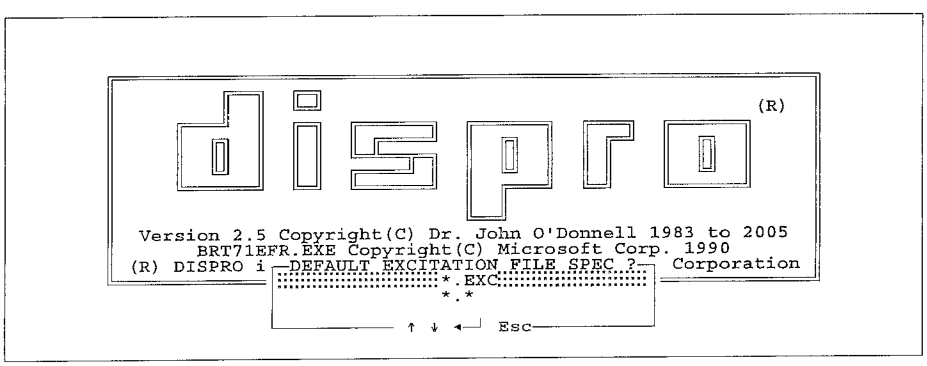


All filenames with the extension of .FDF are shown — you select the desired filter data file by means of the highlight bar.

```
Directory for C:\FILTER\DATA\*.FDF
                    Select filter or other data file
                              [Esc to Exit]

 9 File(s) Found

  CHEB208A.FDF  KSR0111A.FDF
  EQR0047A.FDF  ELLIP06A.FDF
  BUTTR17A.FDF
  EQR0049D.FDF
  EQR0049B.FDF
  EQR0049A.FDF
  KSR0223A.FDF

 Filename : CHEB208A.FDF


Use cursor keys to select file then press <ENTER>
```

The forced time response computation is the only option which requires two file names — one filter data file and one excitation data file. When the excitation data file is created by the WAVEGEN module (the *Generate Test Signal* option) the default filename extension is .EXC. Thus, when computing a forced time response you will be given the usual choice of directly specifying a file name or selecting a file from a directory listing. If you choose the directory listing you will then be asked to choose the default specification for the directory listing. The .EXC extension is the default choice — selecting *.* will show all files except those with excluded extensions as described above.





The files with extension .EXC are displayed for your selection.

```
Directory for C:\FILTER\DATA\*.EXC
                  Select filter or other data file
                           [Esc to Exit]

 1 File(s) Found

 UNIT.EXC

 Filename : UNIT.EXC

Use cursor keys to select file then press <ENTER>
```

1.3 Program Limits

It is necessary to provide some maximum sizes for various data and parameter arrays. Values have been chosen that are consistent with useful engineering problem parameters.

IIR Filters: Maximum filter order is 99 for Lowpass and Highpass, and 98 for Bandpass and Bandstop.

FIR Filters: Maximum lengths are 1024 for the EQ or Equiripple (Parks-McClellan-Remez) designs, and 8191 for Kaiser windowed designs. Be cautious in designing long EQ filters; computation times can be extended. For example, for bandpass filters of lengths 220 and 330, computation times of 5.5 minutes and 16 minutes, respectively, were experienced on a 10 MHz 286 PC with an 8 MHz 80287. Practical lengths, less than 100, are done in less than a minute. By contrast, the Kaiser design is almost instantaneous for lengths less than 200, and requires a minute or so for lengths up to 8191.

Frequency Response: For IIR and FIR filters, up to 1000 spectrum values can be computed, covering any desired segment of the frequency range between d-c and one-half of the sampling frequency. The response computation may be specified either by the number of points in a frequency range or by the spacing between points on the frequency axis. As an additional option for FIR filters, up to 4096 spectrum values between d-c and one-half of the sampling frequency may be efficiently computed with the FFT.

Impulse/Step/Time Response: Time sample sequences up to 2048 points long (0 to 2047).

Spectral Analysis: Up to 8192 real-valued time samples can be FFTed to produce up to 4096 complex-valued (magnitude and phase) frequency samples.

Test Signal Generation: Up to 100 sinusoidal components may be specified for synthesizing a time sample sequence of up to 2048 points. Gaussian white noise of specified variance may be added to the time sample sequence. Up to 2048 samples of other special waveforms.