This is the opening screen with the **File** menu item pulled down. All data input and output for the program will occur through the selection of items from this menu area.

This menu item is initially disabled. Its function is to normalize the transfer function frequency response to a specified level, either at d-c or at the peak of the response. It can be enabled using a check-marked menu item under the **Options** main menu item.

s-to-z Transfer Function Conversion

| File | Options | ShowValues | GainAdjust |

TransferFunction ▶

Restart

Print Freq Resp
Print Coefficients

Exit

Transfer Function specifications may be input via the keyboard, or from a .TFF file (s or z), or from a .FDF file (z-domain filter designed by DISPRO .

This will allow you to start over without exiting the program

Outputs the numerical values for the selected frequency response to the default Windows printer (use carefully, 500 points will require 8 or more pages).

Outputs the transfer function coefficients to the default Windows printer

Exit the program

s-to-z Transfer Function Conversion

| File | Options | ShowValues | GainAdjust |

TransferFunction | Open (.TFF or .FDF)

Restart | Save (.TFF)

Print Freq Resp | Keyboard Input
Print Coefficients | Edit ▶

Exit

Selecting **File|TransferFunction|Open (.TFF or .FDF)** will cause a common dialog box to pop up. You will select a .TFF file that you will usually have saved after inputting the specifications from the keyboard. The specifications in this file can be in either the z or s domain. Obviously, you can only save to a .TFF file after opening one, or providing input from the keyboard. (Use **DISPRO** to create a .FDF file.)

By selecting **File|TransferFunction|Keyboard Input** you invoke a series of dialog boxes which allow you to specify up to a 10th-order transfer function. The first dialog box sets the domain for the specifications, and requests a value for the sampling frequency–the default value is 1.0.

The next step in the Keyboard Input process is to select the form in which you will provide the specifications for the transfer function. The maximum order for the transfer function is 10. In order to specify the transfer function as a rational transfer function it must be of order 3 or greater (since a biquad is a rational transfer function of order 2).

An important fact to observe here is that STOZXFR actually makes no distinction between biquads and 1st-order sections as far as storage and processing is concerned. Second order and first order sections are

Specifications Domain

(Specs may be in either s or z domain. If in the s domain the transfer function will be converted to the z domain using the bilinear-z mapping.)

Domain Selection
○ s-Domain
○ z-Domain

Sampling Frequency (Rate) [1.0] Hz

[Accept]   [Cancel]

freely intermingled–this is also true in the .TFF files produced by STOZXFR. As a consequence, there is some inefficiency of realization because Biquad cells will be used for all sections, regardless of the order of the section. For a more efficient implementation you will have to manually segregate any first order sections when the final design has been developed.

If you select either the **Poles and Zeros** or **Biquad (and 1st Order) Factors** option then the next dialog box asks for the
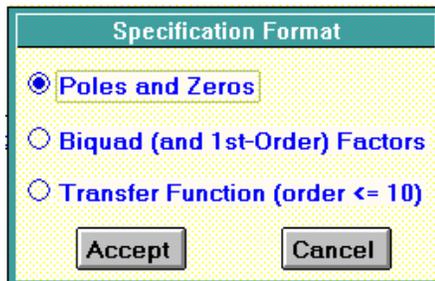
number of sections in the transfer function. Note that the sections can be biquads or 1st-order sections, in any sequence.

If you select the **Transfer Function** option then you must specify the order of the transfer function $(3 \leq order \leq 10)$. The poles and zeros of the transfer function will be computed, and a cascade of biquads, and a single 1st-order section if the order is odd, will be created.
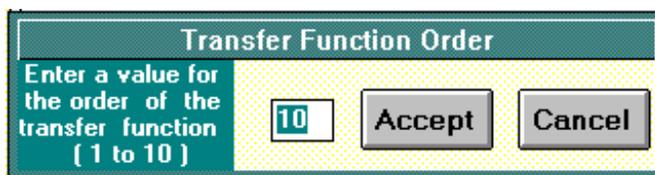
After you have specified either the number of sections, or the transfer function order, a dialog box appropriate to the parameter specification you have chosen will appear. For the **Poles and Zeros** and the **Biquad (and 1st Order) Factors** options each section must be specified also to be of first or second order. This dialog box will appear each time a section is to be specified. For the first section it will appear alone; for succeeding sections it will pop up over the dialog box in which the parameters are to be entered.
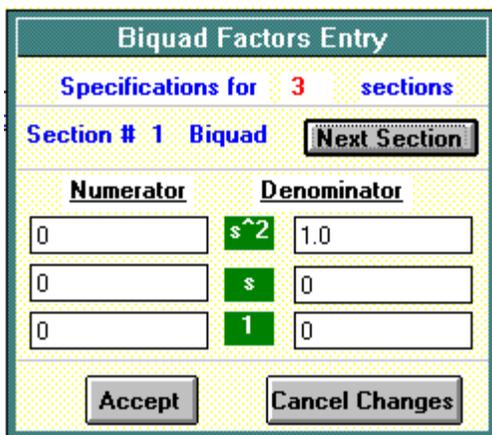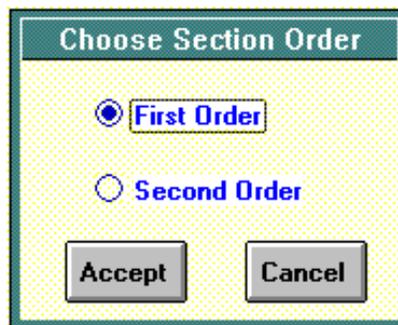
For the **Biquad (and 1st Order) Factors** option the dialog box requires the coefficients for the numerator and denominator. Depending upon the domain you have chosen, the coefficient labels will be powers of either s or z. If you have specified this section to be of second order, then the denominator must be a quadratic–the numerator is not restricted. To enforce the quadratic nature of the denominator, the coefficient of s^2 or z^2 is fixed at 1.0 and cannot be changed. When there is more than one section to specify, you use the **Next Section** button to cycle through the sections. Only when all sections have been specified should you click the **Accept** button. Clicking the **Cancel Changes** button will abort the specification process–new values in the text boxes will be cleared.

For the **Poles and Zeros** option, the same *Choose Section Order* box will pop up, but the pole and zero values will be entered on a form which allows you to select the kinds of poles and zeros for the section, and then to enter the values in the enabled text boxes. Again, if the section was specified as second order then there must be either a complex-conjugate pole pair or a pair of real poles–there is no restriction on the type of zeros. For the s domain, the poles and zeros must be in the left-half plane–so the real part must be negative–although a complex- conjugate zero pair can be on the jΩ axis. For the z-domain, the pole and zero values will be inside the unit circle–except that complex-conjugate zeros may be on the unit circle–and will be specified by their radius and, if complex, by their angle in **Hz**. As with the entry of biquad coefficients, you use the **Next Section** button to cycle through the sections of the transfer function. You must provide values for all sections *before* selecting the **Accept Button**.

The final data category for keyboard input is a **Transfer Function** specification. This is a rational transfer function, the order of which is specified before the coefficient dialog box appears. The enabled text boxes depend on the order specified, up to 10. Here, for a third-order transfer function, note that the denominator coefficient for the highest power of s or z is fixed at 1.0. The poles and zeros of the transfer function will be computed, and a cascade of biquad sections will be created.

All keyboard input, whether in the form of poles & zeros, biquad section coefficients, or transfer function coefficients, is checked for validity–essentially, for stability. If the characteristics of any section present a problem then a message box will flag the offending section, but only after the **Accept** button for the dialog box has been clicked.

After the transfer function has been specified by keyboard input or by opening a .TFF or .FDF file, the z-domain pole and zero values for the transfer function are displayed in the text boxes on the main window (if the input specifications were in the s domain then the z-domain values are for the bilinear-z mapped transfer function). These values can be edited directly (although this is a questionable practice if the original transfer function was specified in the s domain), or they can be incrementally changed by entering an increment value in the appropriate text box and clicking on the up and down "spin" buttons–the red triangles. If the transfer function was specified *via* keyboard
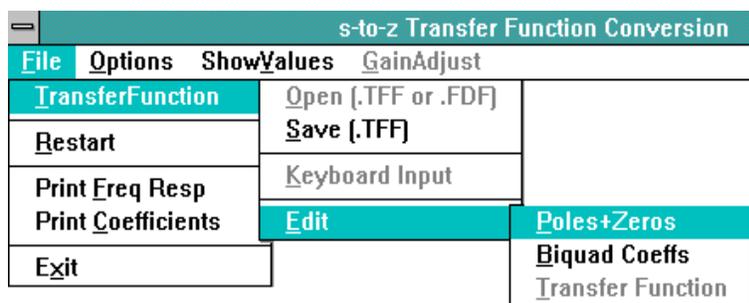
input, then you may edit the values by selecting the **Keyboard Input** menu item again – this is for the situation where you have entered s-plane values and wish to edit in that domain, or if you have entered s- or z-domain coefficients and wish to change coefficient values. If the transfer function was specified by opening a .TFF file then the **File|TransferFunction|Edit** menu item leads to a choice of editing either the poles & zeros, the biquad coefficients, or the transfer function coefficients *as originally input from the keyboard or from a .TFF file*. This is not the same as changing the values in the text boxes in the **Pole/Zero Values** frame. A .TFF file contains, of course, only biquad coefficients. STOZXFR always computes the poles and zeros because these are the primary parameters for modification using the spin buttons. Once more, remember that an s-domain .TFF file produced by–or opened by–STOZXFR has the coefficients organized just as in the z-domain .TFF file.

All computation and plotting of frequency response information is for the frequency range and the number of points entered in the corresponding text boxes in the **Frequency Response Plot Parameters** frame.
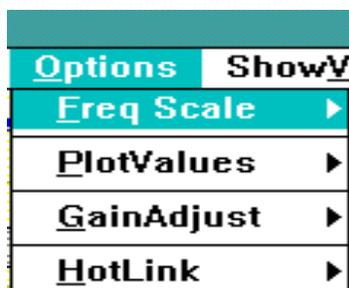
The **Options** menu item provides access to a large number of submenu items, all of which have only the checked/unchecked property–i.e., none of the submenu items causes an immediately visible action. Their function is to set internal flags governing a number of aspects of the program. The four major categories affect the frequency axis scale for the response plots, the values which will be plotted on the frequency response plot, the enabling/disabling of the **GainAdjust** main menu item, and a set of options for establishing "hot" links between the **Pole/Zero Values** text boxes and the graphics plots.

Two choices are available for frequency response plots: linear and logarithmic frequency axis. In both cases the upper limit to the computed response data is set by the sampling frequency. In the linear case the maximum frequency for computation is one-half the sampling frequency–an error message will appear if you click the **Compute** button when the value in the **Frequency (Hz)...*Max*** text box is greater than $F_S/2$, although you can set the maximum value for plotting to any value. If you check-mark the **Log** option then the frequency axis specification changes to **Decade Number**. You can compute and plot over any range of decade values between -10 and +10, but you are restricted to a maximum of 10 decades on a single plot. The maximum decade number can correspond to a frequency greater than $F_S/2$ but the computed data will, of course, stop at $F_S/2$.
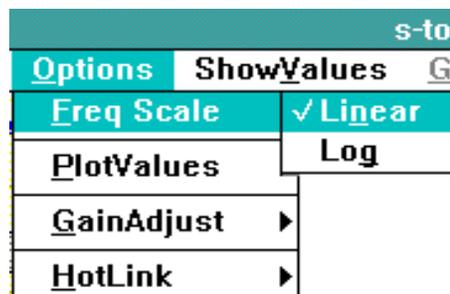
When the transfer function specification is in the s domain then the response of the analog transfer function will be computed and overlaid with the response of the digital equivalent. The analog transfer function response is plotted in green, for both magnitude and phase. The digital transfer function response is plotted in blue for magnitude and red for phase.
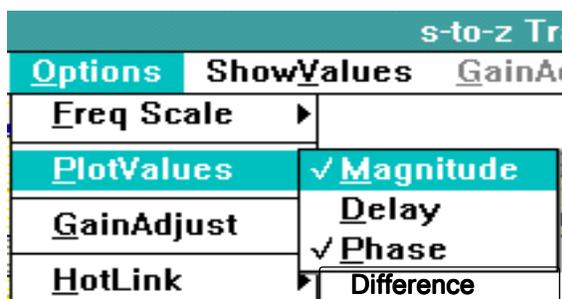
What gets plotted in the frequency response window is determined by the items check-marked here under the **Options|PlotValues** submenu item. The magnitude values can be combined with any one–but not more than one–of the other items. You can uncheck the magnitude item and plot just phase or delay. The plotted quantities will be indicated in the label for the frequency response plotting window. [**NOTE:** the difference between the analog and digital frequency responses has been added to the **PlotValues** sub-menu choices.]

The main menu item **GainAdjust** is initially disabled. This submenu provides a toggle to either enable or disable the main menu item. Why would you want to enable and then use the gain adjust feature? The primary application is to adjust the transfer function response to achieve a desired peak magnitude, or a desired value at d-c. You can always set the gain level of the transfer function using the text box in the Pole/Zero Values frame, but this is for a single section at a time. The gain adjust feature will set all of the section gains proportionally to achieve the desired magnitude level.
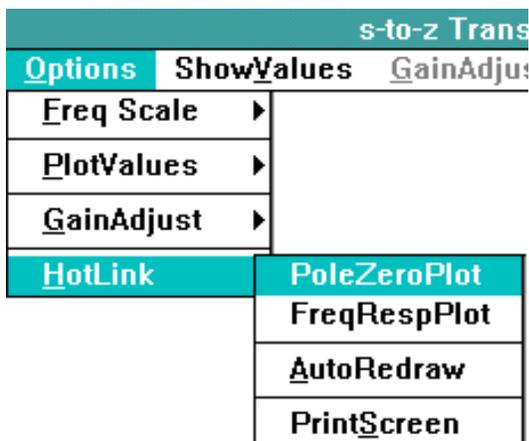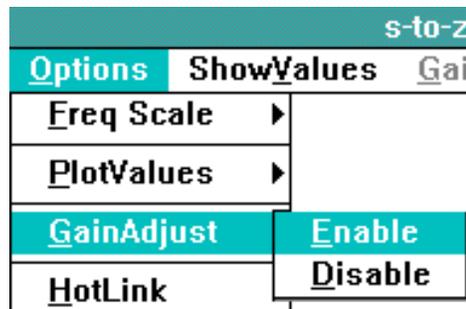
A significant interactive feature of STOZXFR is implemented *via* "hot links" which can be established by check marking these submenu items. Simply stated, a **Hot-Link** means that each time any parameter of the transfer function is modified using the text boxes and spin buttons in the **Pole/Zero Values** frame the check-marked plot is updated. There is, of course, no computation needed for the **PoleZeroPlot**, but the frequency response will have to be recomputed for the **FreqResp-Plot**. It is the hot link to the frequency response plot which is the more interesting and useful. When this hot link is set, each change in the transfer function parameters will cause a new response to be computed and plotted, giving rise to a family of response curves. Changes can be made by clicking the up or down "spin" button, or by typing a new value into the appropriate text box and pressing the ⎗ key. (When the graph becomes too cluttered, just click the **Clear + Replot** button to plot only the current data set.)

At present there is no capability for graphics output to the printer. As a compromise the capability to print the entire screen–including the graphs–is provided. To use this feature you must first check-mark the **Au-toRedraw** menu item, then redraw the plots, then return to this submenu and click on the **PrintScreen** item. Because Windows will keep a bitmapped copy of the entire screen in memory when the Autoredraw property is set, you should remove the check mark after you have obtained the desired hard copy of the screen because otherwise you will be unable to clear either of the plots–Windows has "memorized" them and will keep them on the screen until you turn off the autoredraw function.
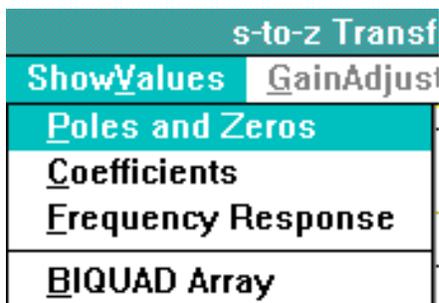
In addition to the information in the textboxes and the graphs, you can view all transfer function parameters and the current frequency response data set in numerical tabular form. Clicking on any of the first three items in the **ShowValues** submenu will bring up a window containing a grid layout for the transfer function's poles+zeros or coefficients, or a scollable list box for the frequency response data set. The displayed frequency response data set will correspond to the last computed response, and you will have the option of viewing either the s-domain (if appropriate), the z-domain response, or the difference between the s- and z-domain responses.

Internally, the transfer function parameters are stored in an array of structures which are identified as being of BIQUAD type; the last item on this menu will pop up a window showing each element of this array, thus providing another way to see the poles, zeros, gain, and coefficients for each of the cascaded sections in the transfer function.

Hard copy of frequency response values can be obtained using the **File|Print Freq Resp** menu item. The output will be the same values you see in the on-screen listbox. Be aware that 500 points will require more than 8 pages of printout. Likewise, the **File|Print Coefficients** menu selection will provide a hard copy of the coeficients for the s-domain or z-domain cascaded sections.

The appearance of the actual printed results will depend on the font currently set for the Windows default printer.
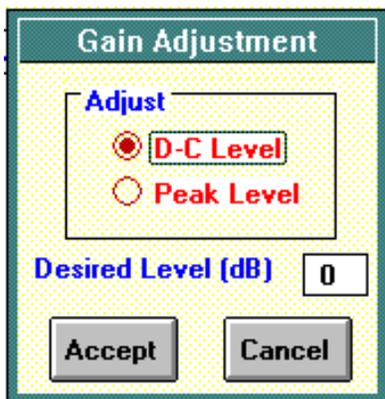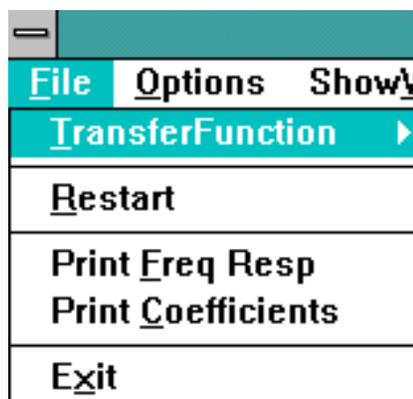
As mentioned above, the **GainAdjust** menu item affects only the transfer function. When the **GainAdjust** menu is enabled and you click it, this window will appear. You make the selection as indicated by the option buttons, and optionally enter a value in the text box for the desired level. Should you choose the **D-C Level** option and the value in the *Min* textbox for the frequency axis is not 0 (which it cannot be if the log frequency axis is in effect), then a message box will pop up requesting confirmation to adjust the gain to the desired level at this minimum frequency. It's your choice. (Note that this is a way to set a desired level at any frequency by making that frequency the minimum value for the currently computed response.)
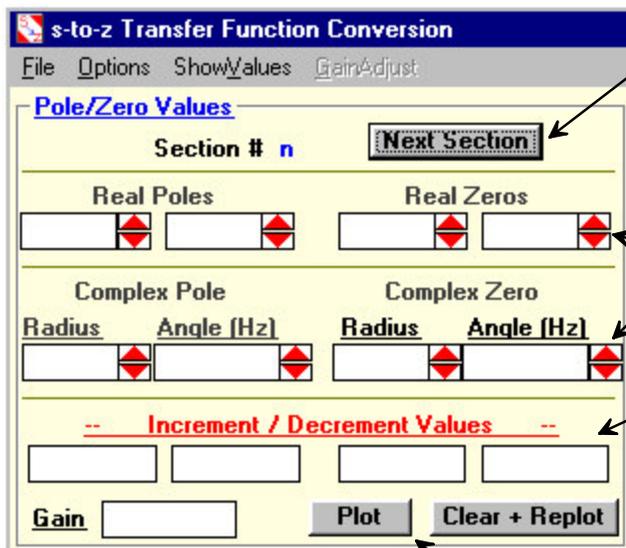
Next Section: Clicking this button will update the pole and zero text boxes with the pole and zero values for the biquad section whose sequence number is displayed in place of "n".

Spin Buttons: These up and down pointers will increment or decrement the zero or pole values each time one of them is clicked.

Increment/Decrement Values: You will enter numeric values into these text boxes. Inc/Dec values for the radius of complex conjugate poles should be rather small, usually not greater than 0.01.

These buttons affect the pole/zero plot. The poles and zeros are not automatically plotted--you must click the **Plot** button for the initial plot. The **Clear & Replot** button is generally used after a number of pole/zero value modifications have been made while the "Hotlink" option is in effect for the pole/zero plot (the plot may be too cluttered).
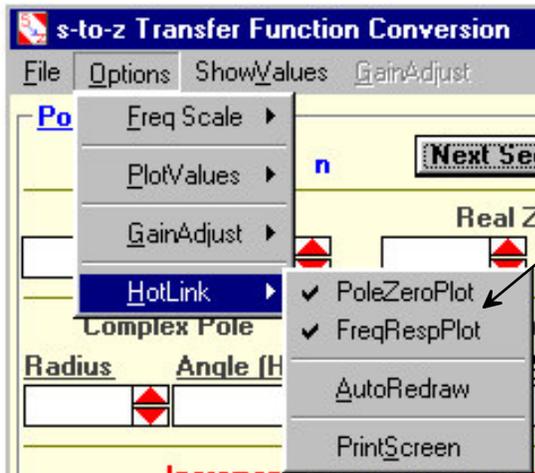
The **HotLink** option is designed to provide a visualization of the way in which the frequency response (and the pole/zero constellation) vary as the pole/zero values are modified. With this option enabled — as indicated by the check marks on the menu items — each time a change is made in either a zero or a pole the frequency response is recomputed and plotted automatically.
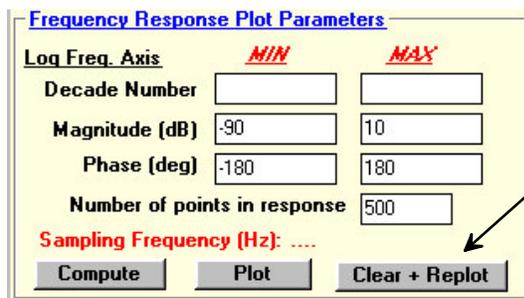
When the plot becomes too cluttered then clicking the **Clear & Replot** button for the frequency response will erase the history and plot the frequency response corresponding to the current values of the poles and zeros