Chapter E: The Signal Averaging Module

Datapac 2K2 User's Manual, Ver 3

Chapter E: The Signal Averaging Module

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E-1. Introduction

The Signal Averaging module is designed to obtain averaged response profiles that are either time-locked or phase-locked to a repetitively occurring trigger or reference event. The term *time locked* means that the response or responses occur at a fixed latency following the presentation of a stimulus. For example, a reflex response usually occurs at a fixed latency following the presentation of an appropriate stimulus, such as an electrical pulse or a patellar tap. In contrast, the term *phase locked* means that the response or responses are presumed to occur at specific phases of a cyclical or recurring activity. For example, certain muscles are normally active during specific components of a gait cycle irrespective of the time it takes to complete the cycle itself. For more information on performing time-locked or phase-locked analyses, see Section E-3.

During a signal averaging analysis data are accumulated from the open data file and stored in a series of internal memory areas called ***"traces"***. Up to 64 traces can be active in an analysis, each one linked to any one channel of the data file. The reference, or "trigger" events that are used to locate the data to be accumulated during the analysis are obtained from an event file linked to one of the data file's event buffers. The design of the signal averaging feature makes it possible to accumulate data obtained from different channels into the same trace, to accumulate data from different regions of the data file, to accumulate data from different data files, and to use different event files as trigger events, all within the same analysis. Moreover, it is possible to save the data accumulated in an averaging analysis, to retrieve those data at a later time, and to add new data to the retrieved data.

After performing an analysis you can view the results in both time series displays and X-Y plots. Additionally, the time series display now allows you to add, subtract, multiply, or divide two traces and to view the results alongside the original traces. We call this feature, new to Datapac 2K2, the *virtual traces* feature. It is described in more detail in Section E-6.5.

Another important change introduced in the Datapac 2K2 version of the Signal Averaging module is the maximum resolution of each trace. The *maximum resolution* is another way of saying the maximum number of points per trace. In earlier versions the maximum resolution was 2,500. In Datapac 2K2, however, there is no maximum: the number of points per trace is limitless. Additional enhancements include the introduction of a new phase-locked analysis mode called "dual normalization", and an increase of the maximum number of traces from 16 to 64.

E-2. Entering the Signal Averaging Module

The **Signal Averaging Window** is the control panel used to set up signal averaging analyses, to execute the analyses, and to open display windows to view the results. An example of the signal averaging window is presented in Figure E-1. A brief description of each option in the window is provided in Table E-1. To access the signal averaging window select the **Analysis|Averaging** option in the main window command bar or select the  icon in the main window tool bar.

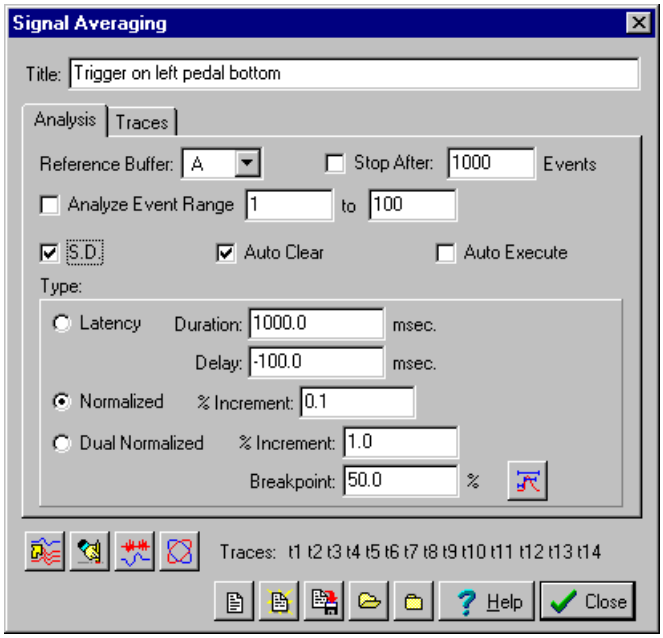


Figure E-1. The Signal Averaging Window.

Note that the Signal Averaging window contains two tabbed sections: **Analysis** and **Traces**. The **Analysis** section contains the parameters that control the type of analysis performed, the reference event buffer (the event buffer that supplies the triggers), the range of events to be used in the reference buffer, and a few other parameters. The **Traces** section contains the parameters that determine which traces are active (i.e., available to accumulate data) and the channels of the data file that are assigned to them. Details are provided in Section E-3. The design of the signal averaging module makes it possible to accumulate data obtained from different channels into the same trace, to accumulate data from different regions of the data file, to accumulate data from different data files, and to use different event files as trigger events in the same analysis. Additionally, with the new ***virtual trace feature***, introduced in Version 2.10 of Datapac 2K2 and described in Section E-6.5, it is possible to add, subtract, multiply or

divide traces. Finally, data accumulated in an averaging analysis can be saved to a file and retrieved at a later time. New data can then be added to retrieved data. Details of the load/save results feature are provided in Section E-3.

Table E-1. Options of the Signal Averaging Window.

Title: A line of text used to describe the set of signal averaging analysis parameters you have defined or will define. The title's primary utility is as a long file name in the event that the parameters are saved to a parameter file so that they may be retrieved in the future.

Analysis Tab

Reference Buffer: This box indicates the letter identifying the event buffer linked to the event file that will supply the reference (trigger) events for the analysis.

Stop After: Check this check box to activate a predetermining counter for the averaging analysis. When active, the program maintains a record of the number of data intervals (sweeps) accumulated in each trace and automatically terminates the analysis when the number of intervals accumulated *in any trace* reaches the value entered in the box to the right of the Stop After check box.

Analyze Event Range: Check this check box to limit the analysis to a selected series of events in the specified reference buffer. Enter the lowest and highest numbered events in the series in the boxes to the right of the Analyze Event Range check box.

S. D.: Check this check box to calculate and record the standard deviation of the mean obtained for each data point in each trace.

Auto Clear: When this check box is checked, any data currently stored in any traces are erased when a new analysis is executed. In other words, this check box prevents data from being accumulated over more than one execution. Clear this check box if you wish to accumulate data from different data files, or from different channels or reference buffers.

Auto Execute: When this check box is checked the program automatically performs a signal averaging analysis immediately upon entry into the Signal Averaging module. The auto-execute feature is intended as a time-saving feature, allowing you to obtain results immediately and with little effort. However, since the parameters that are used to perform the analysis are the parameters that were in effect when you closed the module, this feature is best not used if you constantly change parameters.

Type - Latency: Check this check box to perform a latency analysis. In a latency analysis the program generates average traces for a fixed interval around the selected reference (trigger) events. Details are provided in Section E-3.

Duration: Determines the total length of each trace when a latency analysis is selected.

Delay: Determines the beginning of each trace relative to the onset of the corresponding reference event, when a latency analysis is selected. A negative value positions the start of each trace *before* the onset of the reference event. A positive value positions the start of each trace starts *after* the onset of the reference event. A value of zero means the trace begins at the same time as the onset of the reference event.

Type - Normalized: Check this check box to perform a normalized analysis. In a normalized analysis the duration of each trace is equal to the duration of the corresponding reference event, and the duration of each reference event is normalized to a duration of 100%. Details are provided in Section E-3.

% Increment: Determines the number of increments into which each reference event is divided. For example, a value of 1 means that each event is divided into 1% increments from 0% to 100% (thus there are 101 increments). Likewise, a value of 0.5 means that each event is divided into 0.5% increments (thus there are 201 increments).

Table E-1 (Continued)

Type – Dual Normalized: Check this check box to perform a dual normalized average. In a dual normalized average both the event durations and the inter-event intervals are normalized. The duration of each event, in combination with the inter-event interval that follows it, always sums to a normalized duration of 100%, but the total duration can be distributed among the two parts in any way the user desires. See Section E-3 for details.

% Increment: Determines the number of increments into which each normalized interval is divided. For example, a value of 1 means that each normalized interval is divided into 1% increments from 0% to 100% (thus there are 101 increments). Likewise, a value of 0.5 means that each normalized interval is divided into 0.5% increments (thus there are 201 increments).

Breakpoint: Determines the percentage allotted to the event duration portion of the 100% total normalized duration. The inter-event interval constitutes the remainder. You can enter the desired breakpoint value manually or use the AutoCalculate button.

 **(AutoCalculate):** Click on this button to automatically calculate the Breakpoint value based on the actual durations of the events and inter-event intervals contained in the reference event buffer. Only the event/interevent intervals contributing to the analysis are calculated.

Traces Tab

Traces: Use this list box to highlight the letter of the trace for which you wish to link a channel, or to change the channel already linked to the trace. After highlighting the desired trace, then highlight the channel you wish to assign to it using the **Channels** list box. Finally, check the **Status** check box to accumulate data to the selected trace during your next analysis.

Status: Check this check box to activate the highlighted trace. When a trace is active, data are accumulated to it during your next execution. If this box is unchecked no data are accumulated into the highlighted trace until it is again checked.

Channel: Use this list box to highlight the number of the channel that you wish to assign to the trace highlighted in the **Traces** list box. Finally, check the **Status** check box to accumulate data to the selected trace during your next analysis.

 **(Set All Status):** Click this button to activate all 64 traces (the **Status** check box associated with each one is therefore checked).

 **(Clear All Status):** Click this button to clear the Status check boxes associated with all traces, thus deactivating them.

 **(Clear Trace):** Click this button to erase the data accumulated in the highlighted trace during previous analyses. If data are already accumulated in the trace the **# Events Analyzed** value will be greater than zero.

 # Events Analyzed: This line reports the number of events already accumulated in the highlighted trace during previous analyses. Select the  (**Clear**) button to erase the previously accumulated data from the trace.

Table E-1 (Continued)

Bottom Section

 **(Execute):** Use this button to execute an analysis. Each time you select the Execute button the program accumulates datda into the selected traces. The data are maintained in the traces until you close the signal averaging module or until you clear the information from them using the  (**Erase All**) button, the  (**Clear Trace**) button (in the Traces tab), or the **Auto-Clear** check box. After every execution -- and provided none of the options just described are used -- you can elect to open a different data file, turn different traces on or off, change the channels assigned to each trace, and/or change the event buffer used to define the reference events as well as the range of events used within that event buffer. Then you can execute another analysis to add more data to each trace.

 (**Erase All):** Use this button to erase the contents of all traces, presumably in preparation to perform a new analysis. Note that the **Auto Clear** check box automatically performs the same purpose.

 **(Time Series Display):** Click this button to produce a time series display of the averaged traces.

 **(XY Display):** Click this button to produce an X-Y plot display of the averaged traces.

 **(View Parameters):** Click this button to produce a view window displaying all of the currently established averaging analysis parameters, the channel currently assigned to each active trace, and the number of data intervals currently accumulated in each trace.

 **(Load Parameters):** Click this button to load a set of averaging analysis parameters that you previously saved to a file.

 **(Save Parameters):** Click this button to save the currently established averaging analysis parameters to a file. Once saved you can later retrieve and use the same parameters for future analyses. Use the **Load Parameters** button to retrieve a saved file.

 (**Load Results):** Click this button to retrieve a file previously saved with the **Save Results** button. Such files contain the data accumulated to all traces at the time the file was saved as well as the set of parameters used to accumulate the data. This option therefore allows you to return to an analysis that was previously started.

 **(Save Results):** Click this button to save the data currently accumulated to each trace, as well as the currently established parameters, to a file. The file can then be retrieved at a later time (using the **Load Results** button) and new data can be added.

E-3. Preparing to Perform a Signal Averaging Analysis

Selecting a Reference Buffer

In preparing to perform a signal avearging analysis, one thing you must do is to select a **Reference Buffer** -- that is, the event buffer that will provide the reference events, or "trigger points" for the analysis. The **Stop After** and **Analyze Event Range** check boxes allow you to limit the analysis to a selected number of events, or a selected range of events in the reference event buffer, respectively. These two features may seem redundant, and in some cases they are. But keep in mind that null events, are not counted in the total number of trigger events contributing to an analysis. Consequently, if there are null events in the selected event range, then the number of trigger events actually contributing to the analysis will be less than what the event range boundaries implies. Thus, if you wish to ensure that a known number of events contribute to an analysis, use the **Stop After** feature as well. If you wish to include all of the events in the reference buffer, regardless of how many there are, clear both the **Stop After** and **Analyze Event Range** check boxes.

Selecting the Type of Averaging Analysis

There are three types of Analysis options for you to choose from: **Latency**, **Normalized**, and **Dual Normalized**. Each is described separately below.

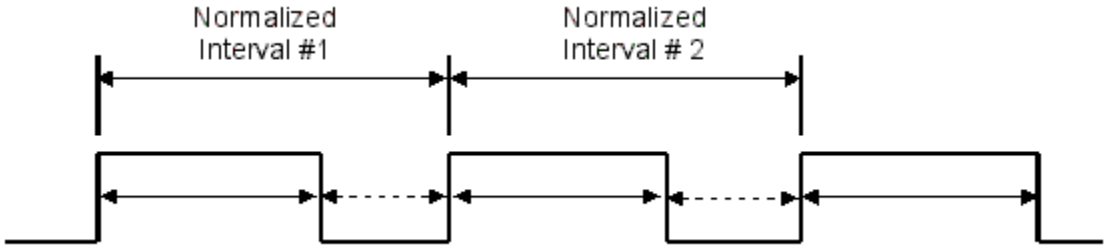
The **Latency** averaging option performs the type of analysis most traditionally associated with a signal averaging instrument: it calculates averaged responses for a fixed interval around the selected reference (trigger) events. This is the type to use if you wish to perform a time-locked analysis. The examination of a reflex response, a stimulus-induced response, or spike-triggered averaging are examples of this type of analysis. Two parameters are specific to the Latency option: Duration and Delay. The **Duration** parameter refers to the total length of the interval for which the averages are developed. The **Delay** parameter allows you to move the beginning of the averaged interval away from the onset of the reference events. A negative value means the interval starts *before* the onset of each reference event. Likewise, a positive value means the interval starts *after* the onset of each reference event, and a value of zero means the averaged interval begins *with* the onset of each reference event. For example, to perform an averaging analysis over an interval of 1 second beginning 200 milliseconds before the onset of each reference event, set the Duration parameter to 1000 and the Delay parameter to -200.

The **Normalized** option develops averaged responses over the duration of the reference events, where each reference event is normalized to a duration of 100% and divided into a number of equal-sized increments. The analysis of gait, where it is desired to measure activity in terms of percentages of the average duration of a step cycle, is a good example of this type of analysis. The **% Increment** parameter determines the number of increments into which each reference event is divided. For example, a value of 1 means that each event is divided into 1% increments from 0% to 100% (thus there are 101 increments). Likewise, a value of 0.5 means that each event is divided into 0.5% increments (thus there are 201 increments). One data point is accumulated in each trace for each increment over the duration of each event.

The **Dual Normalized** option develops averaged responses by normalizing both event durations and interevent intervals. Since an event duration is the time between the onset and offset of an event and the interevent interval is the time between the offset of an event and the onset of the next event, the interval that is normalized in a dual normalized averaging analysis is the onset of one event to the onset of the next. The event duration and the subsequent interevent interval are normalized independently, but must always sum to a duration of 100%. Thus, if the event duration equals 60% of the entire interval, the interevent interval must equal 40% The **Breakpoint** value determines the percentage of the total that is constituted by the event duration portion of the interval. A value may be entered manually, or you can use the  (**Auto-Calculate**) button to automatically compute the breakpoint from the event duration and interevent intervals contained in the event buffer that is designated as the reference. The Auto-Calculate option calculates only those normalized intervals that will eventually contribute to the analysis,

taking into consideration the selected **Stop After** and **Analyze Event Range** settings. It is important to recognize, however, that any change in the analysis set-up parameters does not automatically cause the breakpoint value to be re-calculated. Consequently, if you change any of the parameters after clicking the Auto-Calculate button, click it again just before you are ready to perform the analysis to update the value.

The operation of the dual normalized averaging option is illustrated in the example below. A series of three successive events are represented by the the square wave pulses. The rising edge of each pulse represents the onset of the event and the falling edge the offset. The duration of the event is represented by the indicator line running through each pulse. The interevent interval is represented by the broken indicator line between the offset of one pulse and the onset of the next. The intervals that are normalized in the analysis are represented by the indicator lines above the pulses. Note that there is no normalized interval associated with the last event. That is because no interevent interval can be calculated for it. And since no interevent interval exists for that event, no normalized interval is computed. Null events have a similar effect on the analysis. That is, if a valid event is followed by a null event, no interevent interval can be calculated for the valid event, and thus it does not contribute to the analysis.



Selecting the Channels to Average

The signal averaging module provides a total of 64 "traces", or internal memory areas, to store the data accumulated during an averaging analysis. One channel can be assigned to a given trace at any one time. However, the same channel can be assigned to more than one trace at the same time. Likewise, different channels can be assigned to the same trace at different times.

Activating traces and linking channels to them is performed in the Traces tab of the Signal Averaging window. An example of the Traces tab is shown in Figure E-2. To link a channel to a trace, click on the **Traces** tab in the Signal Averaging window, highlight the number of a trace in the **Trace** list box (traces are numbered from T1 to T64), then select a channel number in the **Channel** box. Also be sure to check the **Status** check box to activate the trace. If the Status check box is not checked no data will be accumulated to the trace during an analysis. For example, in the illustration shown in Figure E-2, Trace T4 is the highlighted trace. Its Status check box is checked, making it active, and Channel 4 is linked to it. You must perform the activities just described for each trace you wish to activate.

☞ Active traces are always listed on the line immediately below the Analysis and Traces tabs in the Signal Averaging window. When a given trace is empty the number (actually the “T” in front of the number) associated with it is reported in lower case. Likewise, then the trace does contain data from previous executions, its number is reported in upper case.

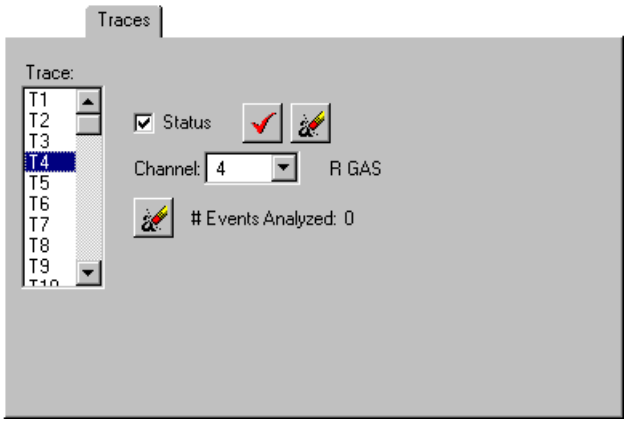


Figure E-2. The Traces tab in the Signal Averaging Window.

The Traces tab also contains a  (Set All Status) and a  (Clear All Status) button. Respectively, these two buttons allow you to activate or deactivate all of the traces all at once. It is important to recognize that the Set All Status and the Clear All Status buttons do not affect the data that are already contained in the traces, if any. They only check and clear the Status check boxes associated with each one. The  (Clear Trace) button, on the other hand, does affect the data stored in a trace. Specifically, clicking it deletes any data that may have already been accumulated to the highlighted trace in previous executions. Likewise, to delete all of the data in all traces, click the  (Clear All) button located below the Traces tab in the Signal Averaging window.

Viewing the Selected Analysis Parameters

Select the  (**View Parameters)** button in the Signal Averaging window to open a window reporting all of the current averaging analysis parameters, the channels currently assigned to each trace, and the number of events contributing the data contained in each. Once displayed the contents of the window can be printed to produce a hard copy log of the analysis parameters you used.

E-4. Performing an Averaging Analysis

After you have selected the type of analysis you wish to perform, the reference buffer you wish to use, and set up the traces as desired, click the  **(Execute)** button to perform the analysis. A progress bar appears in the bottom left corner of the Signal Averaging window as the analysis proceeds, then disappears again when the analysis is completed. At the completion of the analysis many of the buttons and parameter boxes will become deactivated to prevent you from inadvertently making changes that would affect the integrity of the data that is now stored in the traces. If you want to make changes to any of these parameters you must first click on the  **(Erase All)** button to delete all of the stored data.

Note that if the **Auto Clear** checkbox (in the Analysis tab) is left clear the newly accumulated data are appended to any data already accumulated in previous executions. Alternatively, if the **Auto Clear** checkbox is checked, then previously analyzed data are erased before the analysis begins. You can also erase previously accumulated data by clicking on the  **(Erase All)** button located immediately to the

right of the Execute button. To erase the data accumulated in individual traces, use the **(Clear Trace)** button in the Traces tab.

E-5. Performing a Multiple Analysis

Each time you click the **(Execute)** button the program accumulates data into the selected active traces. The data are subsequently maintained in the traces until you close the signal averaging feature or until you elect to erase some or all of the information using the **Auto Clear** checkbox, the **(Erase All)** button, or the (**Clear Trace**) button. Assuming you do not elect to erase the information by one of these methods, you can open a different data file, turn different traces on and off, change the channels assigned to each trace, and/or change the event buffer used to define the reference events as well as the range of events used within that event buffer. Then you can perform another execution and add the newly accumulated information to the previously accumulated information. We call this a **Multiple Analysis.**

Additionally, you can elect to save the accumulated contents of the traces to a file at any time. The file can then be retrieved as desired, and new data can be added at will. Select the **(Save Results)** button to save the traces to a file and select the **(Load Results)** button to retrieve the data previously saved to a file. When a results file is loaded the parameters that were in effect when the file was saved are retrieved along with the data.

E-6. Displaying Results: Time Series Displays

After executing a signal averaging analysis, select the **Display Time Series** button in the **Signal Averaging Window** to produce a time series display of the obtained averaged traces. An example of an averaging results time series display window is shown in Figure E-3. When initially opened the program employs the same parameters that were in use the last time you closed the display. You can change the parameters by loading an averaging results display parameter file or by using the **Format** option in the display's menu bar. Some of the display parameters can also be changed by interacting with hot spots embedded in the display itself, as described in Section E-6.1.

The vertical black line running through the middle of the display box in the example shown in Figure E-3 indicates the location of the reference (trigger) event onset point. This point always serves as the zero point from which time or percentage values are measured. In the case of latency analyses, time values are expressed in millisecond units. In the case of normalized and dual normalized analyses, however, time values are expressed as percentages of the normalized trace duration, which is always 100%. The example in Figure E-3 shows the results of a normalized analysis. Therefore, the starting time value (the value reported above the top left corner of the display box) and the time base value (the value reported below the bottom left corner of the display box) are expressed as percentages of the normalized trace duration.

Note that some of the traces in the example shown in Figure E-3 -- specifically the four traces closest to the bottom of the display -- are surrounded by a series of dots. The distance between the dots and the trace itself is equal to one standard deviation unit -- or one standard error unit, if preferred -- as calculated for point in time throughout the duration of the trace. They serve as a measure of the variability in the average values. Standard deviation or standard error indicators can be added or removed using the Traces tab of the Format window. See Section E-6.4 for details.

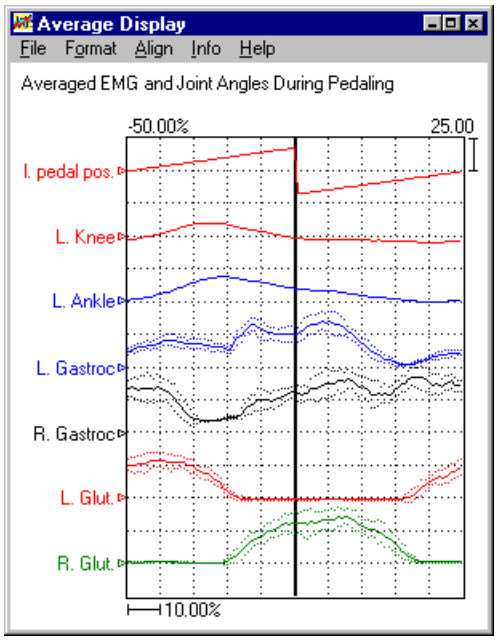


Figure E-3. An example of a signal averaging results display in the time series format.

E-6.1. Display Hot Spots

Hot spots are areas of the display that react to mouse commands to change particular display parameters. The hot spots associated with the signal averaging results time series displays are described in the following paragraphs.

Adjust Duration: Adjust Time Base (Duration): Position the mouse pointer on the time base value located below the bottom left corner of the display box, hold down the CTRL key, then click the left mouse button to increase the time base (i.e., to increase the time interval represented by the distance between successive grid lines) or click the right button to decrease it. The method just described increases or decreases the time base by a factor of two with each implementation. To achieve a more finely tuned adjustment, hold down the ALT key and click the left mouse button. This action opens the menu bar's **Format** option, automatically selects the **Display** tab, and highlights the display **Duration** value so that it may be easily changed.

Align (Position) Individual Traces: Move the mouse pointer outside the left edge of the display box and position it on the letter or title of the trace you wish to move. Press the shift key and hold the left mouse button as you move the mouse. As you do so a horizontal line appears in the display box to monitor the zero reference level of the trace as you move it. A message also appears in the bottom right corner of the window identifying the trace being moved.

Adjust Display Gain of Individual Traces: Move the mouse pointer outside the left edge of the display box and position it on the letter or title of the trace you wish to adjust. Hold down the CTRL key and click the left mouse button to double the gain, or click the right button to reduce it by half. To achieve a more finely tuned adjustment, hold down the ALT key and click the left mouse button. This action opens the menu bar's **Format** option, automatically selects the **Traces** tab, selects the corresponding trace, and highlights its **Gain** value so that it may be easily changed.

Adjust Y-Scale Value: Position the mouse pointer on the Y-Scale value reported above the right corner of the display box. Hold down the CTRL button and click the left mouse button (to reduce the value by one half) or click the right mouse button (to double the value). To achieve a more finely tuned adjustment, hold down the ALT key and click the left mouse button. This action opens the menu bar's **Format** option, automatically selects the **Display** tab, and highlights the **Y-Scale** value so that it may be easily changed.

Change the Display Title: Position the mouse pointer on the existing title of the display (or on the space directly below the menu bar, if no title currently exists), hold down the ALT key, and click the left mouse button. This action opens the menu bar's **Format** option, automatically selects the **Display** tab, and highlights the current **Title** so that it may be easily changed.

E-6.2. Formatting the Time Series Display: An Overview

The Format window, accessed by selecting the **Format** option in the display window's menu bar, is used to set the parameters that affect the appearance of the display. An example of the Format window is shown in Figure E-4. The Format window is broken down into four tabbed sections: **Display**, **Traces**, **Virtual Traces**, and **Information**. The contents of each tab are described briefly below, and in more detail in Sections E-6.3 – E-6.6. In most respects formatting the time series display window available for viewing signal averaging results is very similar to formatting a standard time series display window. Consequently, if you know how to format a standard time series display you should have little trouble formatting an averaging results display.

Display: Add, edit, or remove a title to the display, change the starting time, duration, and overall amplitude scale, turn on/off grid and change its characteristics, turn on/off the display grid and reference line, and other features.

Traces: Add and remove traces and virtual traces from the display, change their display gains individually, apply and adjust amplitude offset values, mark data points with symbols, display only the data points or connect them with lines, add or remove standard deviation or standard error indicators.

Virtual Traces: Define virtual traces. Virtual traces are arithmetic combinations of actual traces. You can add, subtract, multiply or divide traces to obtain a virtual trace.

Information: Select channels to monitor with the Info command cursors.

☞ Many of the parameters contained in the Format window can be more quickly adjusted via hot spots on the display itself. See Section E-6.1 for details.

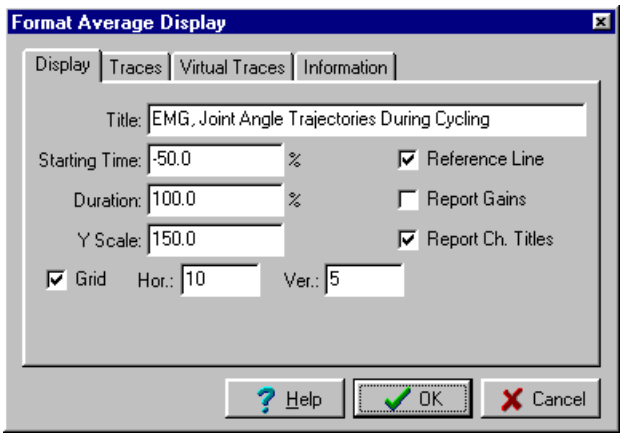


Figure E-4. An example of the Format window associated with the time series results display window.

E-6.3. Formatting the Time Series Display: The Display Tab

To adjust the parameters that affect the overall appearance of a display, select the Format option from the display window's menu bar, then click on the **Display** tab. The contents of the display tab are shown in Figure E-5. The options included in the window are described in Table E-3.

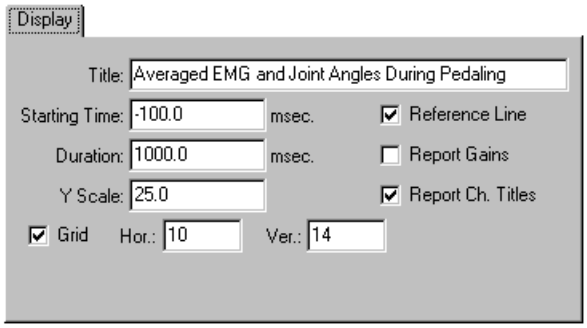


Figure E-5. The display tab of the Format window associated with the time series results display window.

Table E-3. Options of the Display Tab.

Title: A text string that you feel best describes the contents of the display. It appears in the display across the top of the display box. When the display parameters are saved to a parameter file, the display title also serves as the parameter file's title, and it can be used as a long file name when retrieving the file.

Starting Time: Determines the starting time of the display. When using the latency type of averaging the starting time is expressed in milliseconds from the trigger reference point. Negative values indicate the display starts before the trigger reference point while positive values indicate that the display starts after the trigger reference point. When using the normalized type of averaging the starting time is expressed in percentage increments from the beginning of the normalized trace. Values less than 0% and greater than 100% are not allowed.

Duration: Determines the total duration of the display. It can be set to any value equal to or less than the duration of the average traces. When using the latency type of analysis the duration is expressed in milliseconds. And when using the normalized type of analysis the duration is expressed in percentage points.

Y-Scale: Determines the change in amplitude represented by the distance between successive vertical divisions of the display grid. This value applies to all traces within the display.

Grid: This check box turns the display grid on and off. The display grid is the series of horizontal and vertical lines which transect the display box at uniform intervals. The number of grid lines in each axis can be adjusted using the **Hor** and **Vert** boxes.

Reference Line: This check box determines whether or not the reference line appears in the display. The reference line is a vertical line running through the display that marks the time = 0 reference point.

Report Gains: Check this box if you want to report the display gains of each trace in the display. The display gains are indicated in parentheses outside the left edge of the display box, to the right of the letter of the corresponding trace.

☞ Divide the trace's gain by the Y-Scale value to obtain a measure the signal amplitude per vertical division of the display grid.

☞ The display gain does not affect the stored amplitude of the trace.

Report Ch. Titles: When this check box is checked, the titles of the channels currently linked to each trace are reported outside the left border of the display box. When unchecked the letters of the traces are reported instead.

E-6.4. Formatting the Time Series Display: The Traces Tab

The Traces tab contains the parameters needed to add or eliminate traces and virtual traces from the display, as well as the parameters that affect the appearance of each trace. An example of the **Traces** tab is presented in Figure E-6. To add or remove a trace or a virtual trace to the display, first highlight the letter of the trace in the **Trace** list box, then either check the **Status** check box or double-click on the trace letter. When you highlight the letter of a trace or a virtual trace in the **Trace** list box, the parameters associated with it appear in the space to the right. Thus, the information in the right side of the screen changes as you highlight different traces.

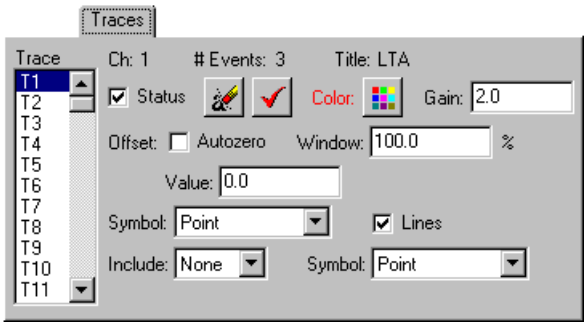


Figure E-6. The traces tab of the Format window associated with the time series results display window.

Table E-4. Options of the Traces Tab.

Trace: This list box lists the traces and virtual available in the signal averaging module. The parameters reported on the right side of the window are associated with the trace currently highlighted in this list box. Consequently, as you highlight different traces the parameter values change accordingly. One of the parameters listed on the right side of the window is the Status parameter. To activate a trace for display, first highlight it in the list box and then check the Status check box.

Ch: Reports the number of the channel currently linked to the highlighted trace.

 # Events: Reports the number of reference events from which data have been accumulated in the highlighted trace.

Title: The title of the channel currently linked to the highlighted trace.

Status: This check box determines whether the highlighted trace appears in the display. Check this check box to include the trace in the display and clear it to remove the trace from the display.

(Clear All): Clears the **Status** check box associated with all traces and virtual traces.

(Set All): Checks the **Status** check box associated with all traces and virtual traces.

Color: Reports the color used to plot the trace in the display. To change the color, select the **(Change Color)** button.

Gain: This parameter sets the display gain for the highlighted trace. The units of measurement for the trace are the same as the channel currently associated with the trace.

Offset (Autozero, Window, and Value): This set of parameters determine the vertical placement of the highlighted trace within the display window relative to its zero reference point. The operation of each parameter are described below.

Autozero: This check box turns the autozero feature on and off. When the autozero feature is on the program calculates the mean amplitude of the first series of data points within the display for the highlighted trace and sets the offset value to the obtained mean *plus* the selected Value parameter. The number of data points contributing to the calculation is determined by the value of the Window parameter.

Window: This parameter determines the number of data points involved in the calculation of the trace's mean amplitude. The mean amplitude is then used to auto-zero the trace in the display. When performing a latency analysis the Window value is expressed in milliseconds, and when performing a normalized analysis the value is expressed in percentage points. The Window always starts at the beginning of the display.

Value: When the Autozero check box is unchecked the Value parameter directly determines the magnitude of the offset applied to the channel. When the Autozero check box *is* checked, however, the mean amplitude of the channel is determined for the duration indicated by the Window parameter, and *then* the Value parameter is applied to the result. The units of measurement employed are the same as the channel currently associated with the highlighted trace.

Symbol: Determines the type of symbol used to mark the locations of the data points plotted for the highlighted trace.

Lines: Check this check box to connect successively plotted data points with lines. Clear the check box to disconnect them.

Include, Symbol: The **Include** box determines whether the plot of the highlighted trace is surrounded with a series of points at one standard deviation unit or one standard error unit above and below the plot. The **None** option results in no points being plotted. The **Symbol** box determines the symbol used to plot the standard deviation/standard error points, when you elect to include them in the display.

☞ You can display the standard deviation or standard error only if you checked the Standard Deviation check box in the averaging parameters window before performing the analysis.

E-6.5. Formatting the Time Series Display: The Virtual Traces Tab

The **Virtual Traces** tab contains the parameters needed to define virtual traces. A ***virtual trace*** is the result of a matrix arithmetic computation performed on two other traces or virtual traces. Stated less technically, you can add, subtract, multiply, or divide two traces or virtual traces point-by-point and "store" the results in a virtual trace.

An example is presented in Figure E-7A in which trace “B” is subtracted from trace “A” to obtain a virtual trace, “A-B”. Virtual traces are so called because they are computed dynamically and are therefore never physically stored. They can, however, be displayed like any other actual trace. They can also be used to compute other virtual traces.

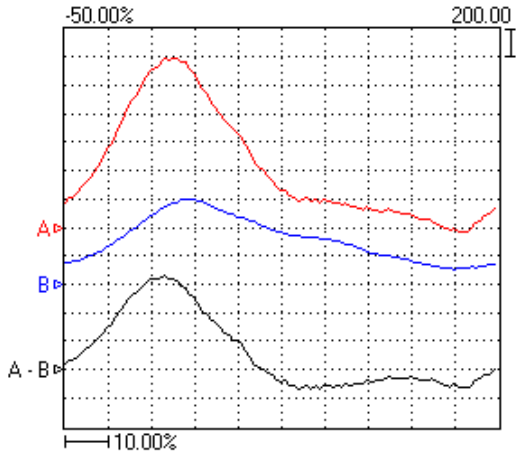


Figure E-7A. An example of a virtual trace (labeled “A – B” that was computed by subtracting the trace labeled "A” from that labeled “B”.

An example of the **Virtual Traces** tab is presented in Figure E-7B. Note that virtual traces are identified with a “V” followed by a number from 1 to 64. The “V” thus serves to distinguish them from actual traces (which are identified by the letter “T” preceding the number). To define a virtual trace, highlight its label in the **V. Traces** list box, then indicate the letters of the two traces (or virtual traces) you wish to compare in the two **Trace** boxes, and the type of arithmetic operation to be performed in the **Operator** box. The **Title** is optional, but does help identify the contents of the trace in displays and elsewhere.

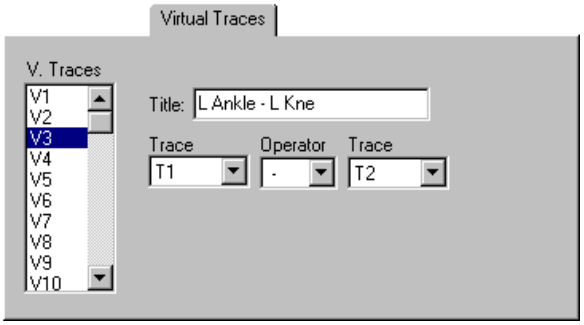


Figure E-7B. The virtual traces tab of the Format window associated with the time series results display window.

E-6.6. Formatting the Time Series Display: The Info Tab

The **Info** command that is available in the time series display window's menu bar produces two vertical cursors which can be moved through the display to measure time and amplitude as well as a variety of statistics. The **Info** tab of the Format window is used to identify which traces or virtual traces are monitored by the cursors. An example is shown in Figure E-8. The cursors are identified by the side of the display where they initially appear. Thus, the **Left Trace** list box determines which trace or virtual trace is monitored by the left cursor and the **Right Trace** list box determines which trace or virtual trace is monitored by the right cursor.

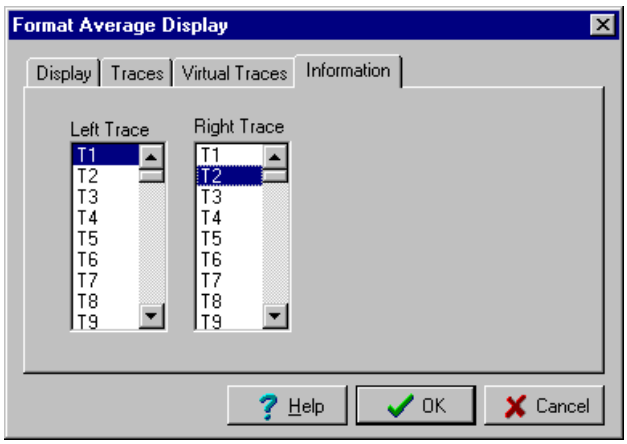


Figure E-8. The info tab of the Format window associated with the time series results display window.

E-6.7. Aligning Traces

Aligning traces means positioning them along the vertical axis of the display. There are two methods available: Auto-aligning and manual aligning.

Auto-Aligning: To auto-align the traces in a display first select the **Align** command from the menu along the top of the window to reveal the two types of auto-aligning: Space and Collapse. Select the **Space** option to equalize the vertical distance between the zero reference points of adjacent traces. Individual traces can then be re-aligned by clicking on the letter of the trace located along the left edge of the display box. Select the **Collapse** option to combine the zero reference points of all traces in the display. Once collapsed the traces remain combined until you select the Space option again.

Manual Aligning: To manually align a trace, move the mouse pointer outside the left edge of the display box and onto (or near) the letter of the trace you wish to realign, then click and hold down the left mouse button. As you do so a text message appears in the left corner of the window below the display box indicating that the selected trace is being moved. In addition, a horizontal line appears in the display to mark the current location of the trace's zero reference point. Move the mouse to move the reference point to the desired location and release the left mouse button.

E-6.8. Loading Display Parameters

When an averaging results display window is first opened the default parameters used to initially construct the display are the ones that were in effect the last time the display window was closed. Once opened, however, a user generated parameter file may be used to reinitialize the display. Loading a set of display parameters is a fast and easy way to set up a display. A given set of display parameters includes all of the parameters listed in the Format parameters window, as described in Sections E-6.3 – E-6.6.

To load a set of display parameters, select the **File|Load Display Parameters** option of the menu bar at the top of the display window. However, to load a set of display parameters you must have previously saved them to a file.

E-6.9. Saving Results Display Parameters

The currently selected display parameters are automatically stored to the default parameter file whenever the display window is closed. Those parameters become the new default values when the results display window is subsequently reopened. Users can also save the currently selected display parameters to their own files so they may be retrieved (loaded) and used in the future. Like the default files, each user-generated results display parameter file contains all of the parameters listed in the Format window.

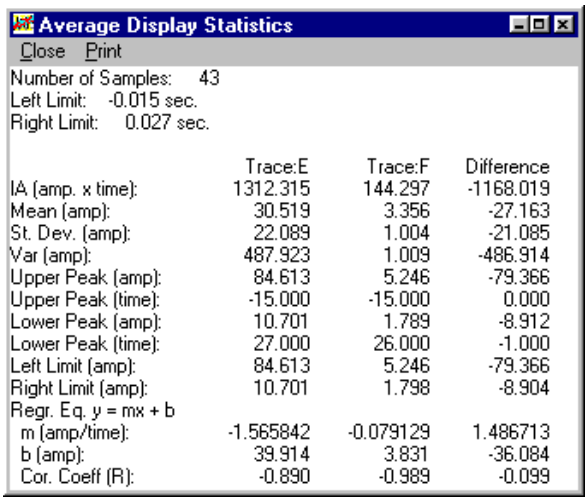
To save parameter file, select the **File|Save Display Parameters** option of the menu bar at the top of the display window.

E-6.10. Using the Info Command

The **Info** command can be used to obtain the time and amplitude of any two points in the displayed data and the difference between them, or to obtain a table of statistics computed for the interval between the two points. When you select the command a drop-down menu containing three options appears: Time/Amplitude, Statistics, and Set Traces.

Time/Amplitude: This option measures the time and amplitude of two data points and the difference between them. After selecting the Time/Amplitude option a pair of vertical cursors are added to the display, one along the left border and the other along the right border of the display box. Additionally, the time and amplitude of the data point monitored by each cursor, as well as the difference between them, are monitored and reported in the top right corner of the display box. Use the **Set Traces** option to select the trace monitored by each cursor. To move one or the other cursor, position the mouse pointer near one of the cursors, hold down the shift key on the keyboard, then hold down the left mouse button and move the mouse. The cursor then jumps to the tip of the mouse pointer and moves with the pointer until you release the mouse button. Press the right mouse button to close the Time/Amplitude option.

Statistics: This option works in the same way as the Time/Amplitude option except that when you press the right mouse button to finish the operation of the cursors a table of statistics appears on the screen. As the example presented in Figure E-9 illustrates, the table reports the number of samples (data points) in the interval, its left and right limits (boundaries), and then lists several statistics computed over the selected interval for each of the two traces monitored by each cursor, as well as the difference between them. These statistics include integrated amplitude (IA), mean amplitude, standard deviation and variance of the mean, the minimum and maximum amplitude (lower peak and upper peak) and the time that they occurred, the amplitude at the left and right boundaries (limits) of the interval, the slope and intercept of the regression line computed for amplitude over time and the correlation coefficient.



Average Display Statistics

Close Print

Number of Samples: 43
Left Limit: -0.015 sec.
Right Limit: 0.027 sec.

	Trace:E	Trace:F	Difference
IA (amp. x time):	1312.315	144.297	-1168.019
Mean (amp):	30.519	3.356	-27.163
St. Dev. (amp):	22.089	1.004	-21.085
Var (amp):	487.923	1.009	-486.914
Upper Peak (amp):	84.613	5.246	-79.366
Upper Peak (time):	-15.000	-15.000	0.000
Lower Peak (amp):	10.701	1.789	-8.912
Lower Peak (time):	27.000	26.000	-1.000
Left Limit (amp):	84.613	5.246	-79.366
Right Limit (amp):	10.701	1.798	-8.904
Regr. Eq. $y = mx + b$			
m (amp/time):	-1.565842	-0.079129	1.486713
b (amp):	39.914	3.831	-36.084
Cor. Coeff (R):	-0.890	-0.989	-0.099

Figure E-9. An example of the statistics window accessed through the **Info|Statistics** option of the time series results display menu bar.

Set Traces: This option selects the trace monitored by each cursor. When you select this option you are transported to the Information tab of the Format window. See Section E-6.6 for details.

E-7. Displaying Results: X-Y Plot Displays

Select the **Display XY Plot** button in the **Signal Averaging Window** to produce an X-Y plot display of the obtained averaged traces. An example of an averaging results X-Y plot display window is shown in Figure E-10.

When initially opened the display window employs the same set of parameters that were in effect the last time the window was closed. Parameters can then be adjusted by loading an averaging results display parameter file or by using the **Format** option in the display's menu bar. Some of the display parameters can also be changed by interacting with hot spots embedded in the display itself, as described in Section E-7.1.

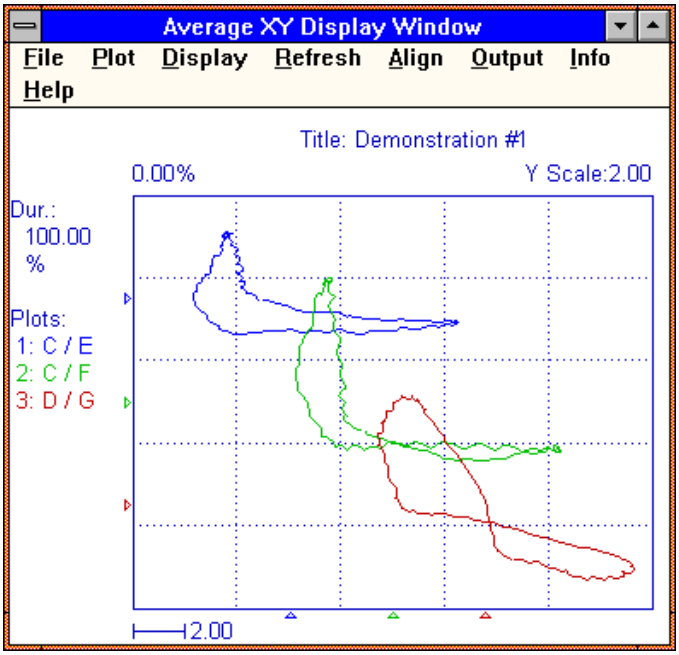


Figure E-10. An example of a signal averaging results display in the X-Y plot format.

You can adjust the display parameters by loading a previously saved display parameter file or by using the **Display** and **Plot** options in the display window's command bar. Some of the display parameters can also be changed by interacting with *hot spots* in the display itself. The display hot spots are described in Section E-7.1. The **Display** option of the command bar opens a parameter window containing the parameters that control the over-all appearance of the display. The **Plot** option opens into a menu of four options, each of which opens a parameter window containing the parameters that control the appearance of one of four individual plots that you can elect to include in the display. Each plot consists of one trace plotted against another. The example presented above contains three such plots.

E-7.1. Display Hot Spots

Hot spots are areas of the display that react to mouse commands to change particular display parameters. The hot spots associated with the signal averaging results X-Y plot displays are described in the following paragraphs.

Adjust Duration: The duration of the display is indicated to the left of the display box. To change the duration, position the mouse pointer over the duration value and double-click the left mouse button to double the duration or double-click the right mouse button to reduce it by one half.

Adjust the Position of a Plot: The zero reference points in the X and Y dimensions are indicated for each plot with arrowheads along the left and bottom borders of the display box, and they are presented in the same color as the plot itself. To adjust the position of a plot, move the mouse pointer over one of the arrowheads, hold down the left mouse button and move the arrowhead to a new location.

Adjust Display Gain of Individual Plots: The traces contributing to each plot are reported to the left of the display box. The relative zero points of the X and Y axes are indicated for each plot in the display with arrowheads along the left and bottom borders of the display box. Both the trace list and the relative zero point indicators are presented in the same color as the plot itself. To increase or decrease the gain of a plot in *both* the X and Y dimensions, position the mouse pointer over the list of traces for the corresponding plot and double-click the left or the right mouse buttons, respectively. To increase or decrease the gain of a plot in *either* the X *or* the Y dimension, position the mouse pointer over the arrowhead indicating the relative zero reference for the corresponding plot.

Adjust Y-Scale Value: Adjusting the Y-scale value affects the magnitude of all plots in the display. To adjust the Y-scale value, move the mouse pointer over the Y-Scale value reported above the right corner of the display box and double-click the left mouse button to double the value or double-click the right mouse button to reduce the value by one half.

Adjust X-Scale Value: Adjusting the X-scale value affects the magnitude of all plots in the display. To adjust the X-scale value, move the mouse pointer over the X-Scale value reported below the left corner of the display box and double-click the left mouse button to double the value or double-click the right mouse button to reduce the value by one half.

E-7.2. Adjusting the X-Y Plot Results Display Parameters

Collectively speaking, the display parameters are the parameters that determine the appearance of the entire display and all of its contents. However, to make them more manageable, the display parameters are separated into two categories: (1) those that affect the overall appearance of the display and, (2) those that affect the individual plots that are presented in the display. The parameters that affect the overall appearance of the display are accessed through the **X-Y Display Parameters Window** whereas the parameters that affect the individual plots are accessed through a series of four **X-Y Plot Parameters Windows**. There is a separate window for each of the four possible plots that can be presented in a display.

Only the parameters that are accessed through the X-Y Display Parameters Window are described here. For a description of the parameters that affect the individual plots, refer to Section E-7.2.

To adjust the parameters that affect the overall appearance of a display, select the **Display** option from the display window's command bar to open the **X-Y Display Parameters Window**. An example of the parameter window is presented in Figure E-11.

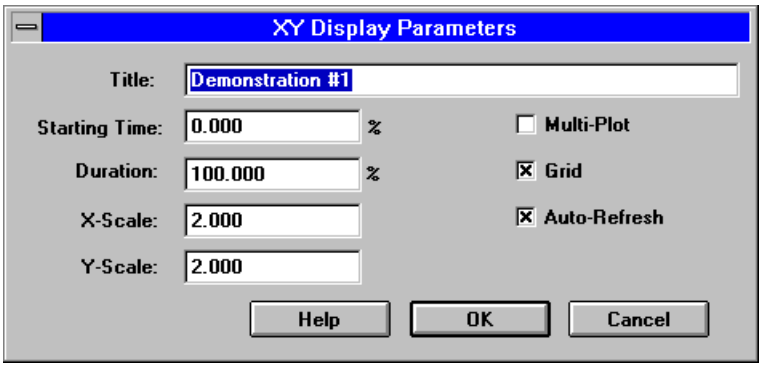


Figure E-11. The display parameters window associated with the X-Y plot results display window.

Table E-5. Options of the X-Y Plot Display Parameters Window.

Title: A text string that you feel best describes the contents of the display. The title appears above the display box, just to the right of the scroll bar. If you save the display parameters to a parameter file, the display title also serves as the file title, and you can use it as a long file name to retrieve the file.

Starting Time: Determines the starting time of the display. If you are using the latency type of averaging the starting time is expressed in milliseconds from the trigger reference point. Negative values indicate the display starts before the trigger reference point while positive values indicate that the display starts after the trigger reference point. If you are using the normalized type of averaging the starting time is expressed in percentage increments from the beginning of the normalized trace. Values less than 0% and greater than 100% are not allowed.

Duration: Determines the total duration of the display, and it can be equal to or less than the duration of the average traces. When performing a latency analysis the duration is expressed in milliseconds. And when performing a normalized analysis the duration is expressed in percentage points.

X Scale: The X-scale value determines the change in amplitude represented by one division of the display grid in the horizontal dimension. This value applies to all plots within the display, and thus the units of measurement are dependent upon the calibration units and the gain associated with each channel assigned to traces that compose a plot.

Y Scale: The Y-scale value determines the change in amplitude represented by one division of the display grid in the vertical dimension. This value applies to all plots within the display, and thus the units of measurement are dependent upon the calibration units and the gain associated with each channel assigned to traces that compose a plot.

Multi-Plot: Turns the multi-plot feature on and off. When the multi-plot feature is off the existing contents of the display are erased whenever the screen is regenerated as a result of a scroll. In contrast, when the multi-plot feature is on the existing contents of the display are preserved when a scroll is effected and the new information is plotted over the existing information. Note that adjusting any other characteristic of the display (such as changing its size or turning one or more channels on and off) eliminates the previous contents of the display.

Table E-5 (Continued)

Grid: Turns the display grid on and off. When the box is checked a grid of horizontal and vertical lines appears in the display. When unchecked the grid does not appear. Note that the time base and Y-scale values are always reported as if the grid was present.

Auto-Refresh: Turns the auto-refresh feature on and off. When the auto-refresh feature is on the display is automatically regenerated (refreshed) whenever any characteristic of the display is changed (e.g., when the display is resized, or when any channel or display parameter is changed). When auto-refresh feature is off the display is only refreshed when you select the **Refresh** option in the menu bar along the top of the display window. Usually it is a good idea to turn the auto-refresh feature off only when it takes a long time to refresh the display.

E-7.3. Adjusting the Plot Parameters

The plot parameters are the collection of display parameters that affect the individual plots presented in an X-Y plot display. For a description of the parameters that affect the overall appearance of the display, refer to Section E-7.2.

The parameters that affect the individual plots are accessed through a series of four **X-Y Plot Parameter Windows**. There is a separate window for each of the four possible plots that can be presented in a display. To access one of the X-Y plot parameter windows, select the **Plot** option in the X-Y plot display window and then one of the options listed as **Plot 1** through **Plot 4**. An example of an X-Y plot parameters window is presented in Figure E-12.

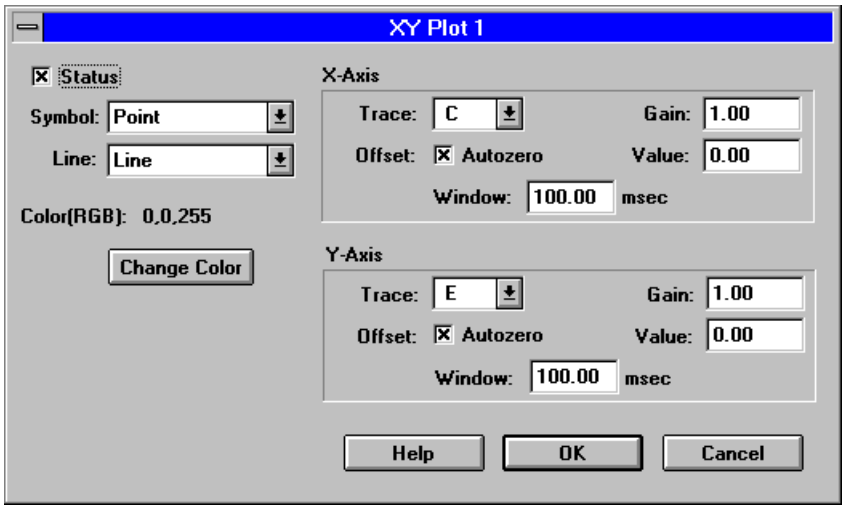


Figure E-12. The plot parameters window associated with the X-Y plot results display window.

Table E-6. Options of the Plot Parameters Window.

Status: Determines whether the plot appears in the display. Check the box to include the plot or clear it to exclude the plot.

Symbol: Determines the type of symbol used to mark the locations of the data points that compose the plot.

Line: Determines whether successively plotted data points are connected with lines (Lines) or not (No Lines).

Color: Reports the color used to present the plot in the display. The color is reported in terms of the intensity of its red, green, and blue components, respectively. To see the corresponding color, or to change the color, select the Change Color button.

Change Color: The Change Color button produces a color palette from which you can select the color used to present the plot in the display. When the palette appears, one of the colors is surrounded by a dotted box to indicate the currently selected color. On occasion the color displayed on the screen does not exactly match the color selected from the palette. That is because lines can only be displayed in "pure" colors, i.e., colors that a single pixel can take on. Most display hardware currently available can produce only 8 or 16 pure colors. Additional colors are achieved by a process called dithering. Dithering is available for coloring area fills but not lines. The traces in an analog display are considered lines.

Channel (X-Axis Section): Determines the channel that is plotted along the X-axis. To change the channel, click on the list box and then highlight the desired channel.

Channel (Y-Axis Section): Determines the channel that is plotted along the Y-axis. To change the channel, click on the list box and then highlight the desired channel.

Gain: The gain parameter sets the display gain for the channel. It works by multiplying the amplitude value of each data point in the channel by the gain value. The units of measurement for the channel in question are determined by the calibration parameters established for it. Thus, they may be different for each channel.

Offset [Autozero, Window, and Value]: The offset parameters determine the placement of the channel plotted along the corresponding axis, relative to its zero reference point. There are three individual parameters within the set: Autozero, Window, and Value.

The **Autozero** check box turns the autozero feature on and off. When on the program calculates the mean amplitude of an interval equal to the value of the **Window** parameter and sets it to zero. The mean amplitude of the interval therefore becomes the zero reference point for that channel. The Window interval is always measured from the starting time of the display. Thus, the mean amplitude is recalculated any time the starting time of the display is changed.

The **Value** parameter is added to the amplitude of each data point in the corresponding channel for the purposes of the display. Thus, it is a way of adjusting the level of the signal relative to its zero reference point. When the **Autozero** box is checked the Value parameter is added to the amplitude value of each data point after the autozero function is performed as described in the preceding paragraph. When the Autozero box is clear the Value parameter is added to the raw amplitude value of each data point.

E-7.4. Aligning Plots in the Display

Aligning plots means positioning the plots within the display box. Generally speaking, there are two ways to adjust the position of a plot within the display box. One way is to adjust the offset of the plot relative to its zero reference point in either the X or Y dimensions (or both). That is done by adjusting the values of the **Offset** parameters in the plot parameter windows accessed through the **Plot** menu of the display window's command bar. The other method of adjusting the position of a plot is to move one or both of its zero reference points. The latter method is described in the remainder of the present section.

Each plot in a display has two zero reference points, one along the X-axis and one along the Y-axis. They are indicated by arrowheads, in the same color as the plot itself, located along bottom and left borders of the display box.

Manual Alignment: The most direct way to reposition a plot's zero reference point is to move the mouse pointer onto the corresponding arrowhead, then hold down the left mouse button as you move the pointer to a new location (the arrowheads are located along the left and bottom edges of the display box). As you do so a line appears in the display to mark the current location of the plot's zero reference point. Additionally, a text message appears in the bottom left corner of the window below the display box to indicate which plot is being moved.

☞ Plots can be aligned individually only when the **Align|Space** option (described next) is in effect. When the **Align|Collapse** option is in effect all plots are moved simultaneously.

Auto-Aligning: The auto-aligning method lets you adjust the zero reference points of all plots at the same time. The zero reference points can either be equally spaced within the display box, or they can be "collapsed" (i.e., all combined into one reference point). To auto-align the plots in a display first select the **Align** command from the menu along the top of the window to reveal the two types of auto-aligning: Space and Collapse. The two types can be used independently in the X and Y dimensions, and therefore there are four alternative options: **Space X Axis**, **Space Y Axis**, **Collapse X Axis**, and **Collapse Y Axis**. The "collapse" options combine the zero reference points on the corresponding axis, thus allowing you to move all plots at once by moving just the one zero reference point (see Manual Alignment above). Once collapsed the zero reference points remain combined (i.e., they cannot be re-aligned individually for each plot) until you select the corresponding space option again.

E-7.5. Using the Info Command

The **Info** command can be used to obtain the amplitude of a plot, relative to a user-selected reference point, in both the X and Y dimensions. When you select the Info command a drop-down menu appears with four options, listed as **Plot 1** through **Plot 4**, corresponding to the four possible plots in the display. After you select one of the options a pair of reference lines, one horizontal and one vertical, appear in the display. The two reference lines initially intersect at the plot's zero reference points (which are marked with arrowheads at the left and bottom edges of the display box)..A line of text also appears above the display box that reports the difference in amplitude between the reference lines and the tip of the mouse pointer in the X and Y dimensions, as well as the diagonal distance between the point of intersection of the two reference lines and the tip of the mouse pointer.

The reference lines can be moved to any location in the display. To do so, move the tip of the mouse pointer to the location you wish to define as the reference point and click the left mouse button. The reference lines then move and intersect at that point.