Logger *Pro*™
User's Manual

Version 1.1

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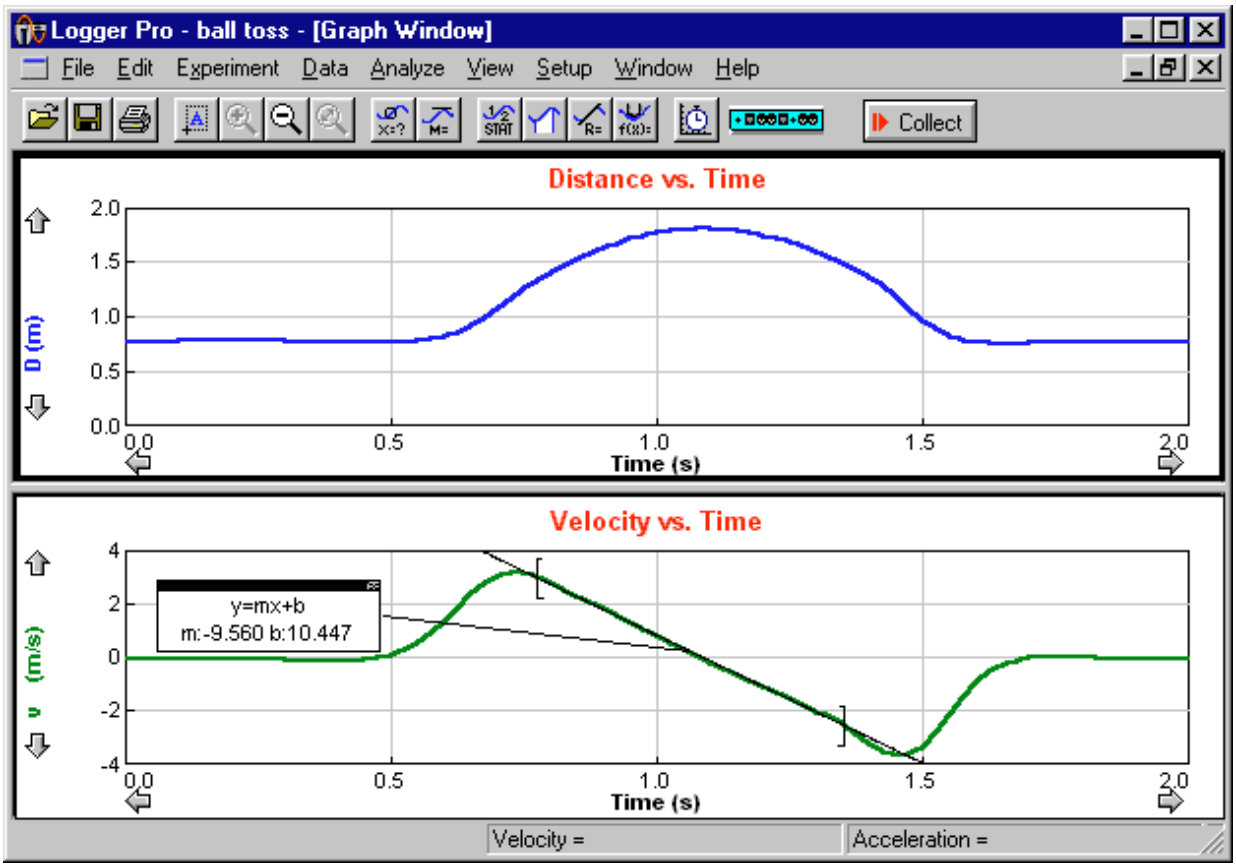

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Logger *Pro*

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Logger *Pro* Overview

Overview

The Logger *Pro* user's guide is divided into four main sections: this overview, a How To section, a Teacher's Guide, and the Logger *Pro* Reference. This Overview concludes with quick-start instructions for the eager. Instructors using Logger *Pro* in the classroom will want to read the Teacher's Guide for helpful tips. The How To section explains common operations with Logger *Pro*. It is designed to be read in any order. The Reference Section explains the function of all the menu items and how to use them. On-line help is available: Choose Help from the Apple menu (Macintosh) or the Help menu (Windows).

The Logger *Pro* tutorials are stapled separately from the user's guide for ease of duplication. We suggest that you read one or both of the introductory tutorials to learn more about Logger *Pro*. One introductory tutorial focuses on using a temperature sensor with Logger *Pro*, and is written for integrated science, chemistry and biology students. The other introductory tutorial uses the Motion Detector and is written for students who will study motion. Additional tutorials teach more advanced skills such as data analysis, curve fitting and defining new columns.

Initial software installation and the connection of the interface are explained in the Teacher's Guide. Refer to the troubleshooting chart in *Appendix A* if you have problems. Detailed information for network use can be found in *Appendix B. Appendix C* reviews the interfaces that can be used with Logger *Pro*, and how to choose between them. A comprehensive list of the sensors compatible with Logger *Pro* is in *Appendix D.*

Some familiarity with the use of the Macintosh or Windows and application software is assumed in this manual.

Logger *Pro*, the Universal Lab Interface and the Serial Box Interface

Logger *Pro*, for use with any Universal Lab Interface (ULI) and the Serial Box Interface, has been designed by Rick Sorensen, Dave Vernier, John Wheeler, David Gardner, Dan Holmquist and John Gastineau of Vernier Software, and by Ronald Thornton and Stephen Beardslee at the Center for Science and Mathematics Teaching at Tufts University. The design was implemented by Stephen Beardslee, Nam Hoang, Mary Dygert, Patrick Powers and Zachari Partridge.

Logger *Pro* Quick Start

Purpose

This section is provided for those who do not read software manuals. It outlines the essential steps to get started with Logger *Pro*.

Install software

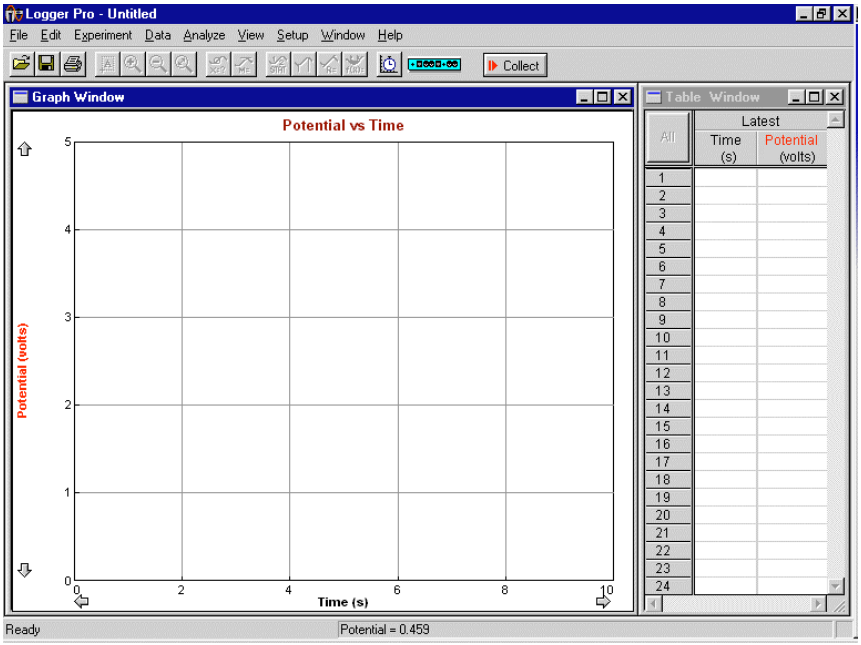
- Insert the floppy disk into your computer and run the installer program.
- Accept the default suggestion for file location.

Attach interface and sensor

- Attach either a ULI or a Serial Box Interface to the computer using the supplied cable. On the Macintosh you can use any serial port, including the modem and printer ports. On the PC you can use any of the COM1, 2, 3 or 4 serial ports.
- Attach the power adapter to the interface and to a source of 115VAC.
- Attach a sensor to the interface. For example, attach a sensor with a DIN (round) connector to the first port, or a Motion Detector with a telephone-style connector to Port2 (ULI only).

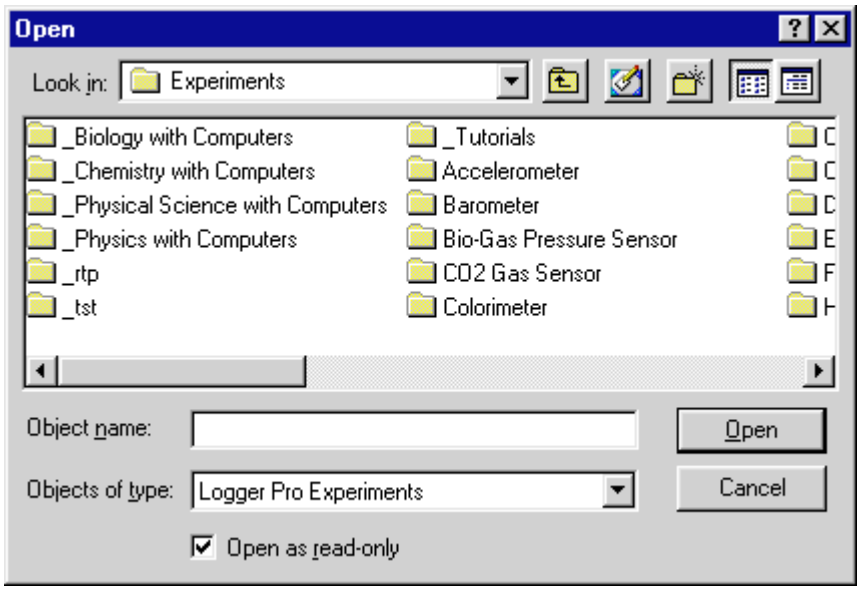
Start up Logger *Pro*

- Locate the Logger *Pro* icon and double-click on it, or use the Start menu (Windows 95/98). You should see the following screen on your monitor.



Configure Logger *Pro* for your sensor

- Choose Open from the File menu, and choose an experiment file from the appropriate sensor folder. For example, if you will use the Barometer, look inside the folder *Barometer* for the barometer experiment files. Calibration is automatically loaded with the experiment file.[1]



Collect data

- Click on the Collect button on the screen. Logger *Pro* should begin plotting data in the graph window.

Adjust graph

You can adjust most features of the graph by double clicking the graph and making changes in the resulting dialog box.

Insert linear regression line

- First, select a portion of the graphed data by dragging across it.

- Then click on the linear fit button on the toolbar.

If you need more

If you need more information for using Logger *Pro*, remember that there is a manual and extensive on-line help.

[1] In Windows 3.1 folder and file names will be truncated to eight characters. For example, the *Barometer* experiment file will appear as BAROME~1.MBL.

Tutorial Overview

Purpose of tutorials

The Logger *Pro* package includes six short tutorials for first-time users, either students or teachers. They are suitable for reference or for duplication and distribution to classes. First-time users should work through one introductory tutorial and the advanced tutorials as needed.

The tutorials are bound separately from this manual for easy duplication.

Introductory tutorials

The first two tutorials, Temperature Measurement and Motion Detection, are both introductions to using Logger *Pro*. Temperature Measurement can be used by all students, while Motion Detection is intended for physics or integrated science students.

Advanced tutorials

The remaining tutorials are intended to be read after either of the first two tutorials are completed, and provide instruction on performing specific tasks with Logger *Pro*. These tasks include

- analyzing data and changing what is graphed
- fitting curves to data
- saving files and printing or transferring data
- creating new columns for data

The advanced tutorials can be done in any order.

Preliminary setup

The tutorials assume that Logger *Pro* has been installed and an interface (a ULI or Serial Box Interface) is properly connected to the computer. Installation instructions are located in the Teacher's Guide.

How To

In the How To section you will learn to perform specific functions in Logger *Pro*, such as using a new sensor or changing data collection rates. You don't need to read this section straight through—just jump to the task you want to perform, and read that portion. The tasks are organized in seven broad categories: graph appearance, sensor functions, data collection options, non-graph windows, data analysis, data tables, and saving and printing data.

If you have further questions, go to the reference section and read the descriptions of the relevant menu items, or check the index for other references.

Change Graph Appearance

There are many ways that you might want to change the appearance of the initial graph. The range of the x or y axis might not be ideal. Or, you might want to plot other quantities on each axis. You can change most elements of the graph directly by clicking on them, so if you are not sure how to change a given item, begin by clicking on it and see what happens. Here are some things you can quickly change on a graph.

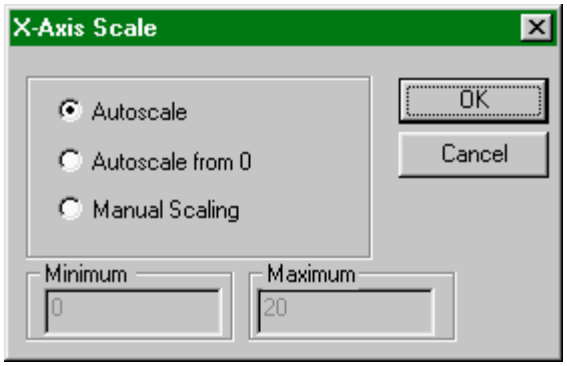
Change axis limits manually

Often you will measure some quantity and the plotted line will only fill a portion of the screen. You can quickly change the range of values plotted by clicking the numbers at the ends of the graph axes. Type a new value and press enter.

Change axis limits automatically

To make the plotted data fill the graph window, click the Autoscale button on the toolbar. 

To change just the x- or just the y-axis limits, click on the desired axis. You will see a dialog box:



Choose the type of scaling you want. Autoscale will set the axis limits so the data just fill the axis. The origin may not necessarily be included unless you choose Autoscale from 0, in which case the origin is always included. Manual scaling allows you to enter the minimum and maximum limits manually. The choice made here will determine how Logger *Pro* scales a new graph.

Zoom in on a graph

To enlarge a portion of a graph to fill the screen, drag across the desired area with the mouse, leaving a rectangle on the graph enclosing the area of interest. Then click on the Zoom In button on the toolbar. If you don't like what you see, you can reverse the action by clicking the Undo Zoom button.  

The Zoom Out button will double the range of both the x and y axes. It does not undo a Zoom In—Undo Zoom does that. 

Scroll to a new portion of graph without rescaling

Sometimes the plotted data will extend off the screen. The arrows at the ends of the vertical and horizontal axes can be used to scroll across the data. Using the scroll arrows is equivalent to changing both extremes of the axis limits at the same time while maintaining the same interval between extremes.

Change what is plotted

The default plot will usually be the sensor output as a function of time or a prompted input. You may want to plot some other quantities. Click either on the x- or y-axis label to get a check box list of all the possible quantities for plotting. Some combinations will not be useful. If you don't see what you want to plot, you may be able to create a new column of data based on the raw data. See *create new columns* below. Once you've defined a new column you can plot it.

Graph two or more sensors simultaneously

You can plot data from multiple sensors either on a single graph or on separate graphs. To use a single graph:

- Click on the y-axis label and select all the sensors you want to plot together. Click on OK

To use several different graphs, you need to create the needed number of graph panes:

- Choose Graph Layout from the View menu.
- Click on the layout with the desired number of panes.
- For each graph click on the axis label for a list of available columns for plotting. Choose the column of the desired sensor.

Plotting one sensor versus another sensor

Sometimes it is appropriate to plot the value of one sensor versus another. For example, you might want to graph pressure as a function of temperature. Once Logger *Pro* is set up to simultaneously take data for the two sensors, click on the axis labels to select the appropriate quantity. A graph does not need to include time.

Arrange windows

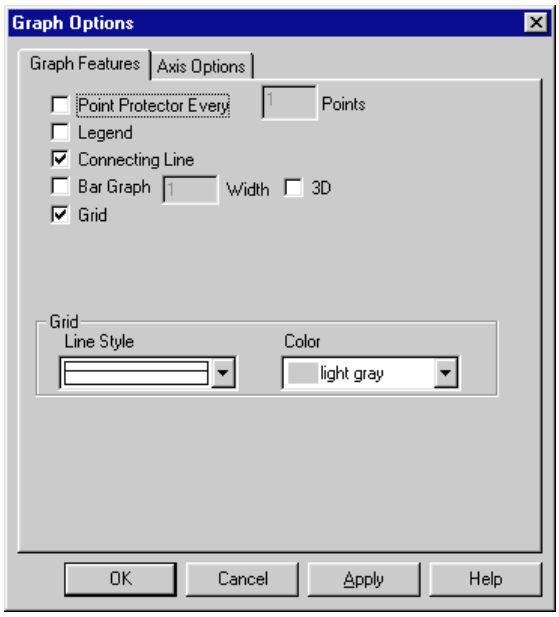
This feature is not available in the current version of Logger *Pro*.

Change the units displayed

The axis labels are shown with physical units whenever they are available. When you set up a new sensor, you can enter the desired units at the same time that you perform calibration. For more information see *sensor setup* below.

Change other graph options

If you double-click on a graph, you will get a dialog box that allows you to change a number of graph options. Brief descriptions follow; for additional information see Logger *Pro* reference.



The following functions are found on the Graph Options dialog. Double click a graph to open this dialog box.

See data points directly (point protectors)

Select point protectors as desired. A point protector outlines a data point. You may want to outline every 5th or 10th point to keep the graph from getting crowded.

Add/remove a legend

Adding a legend opens a floating box holding a key to the plotted data.

Connect data points

Select the Connecting Line option to connect data points with lines. Without this option selected individual data points are visible.

Bar graph

When this option is selected a line is drawn from the horizontal axis to each data point, creating a bar graph. You can control the width in pixels. Setting the 3D checkbox adds simulated depth to the bars.

Add/remove the grid

Select or deselect the grid as desired. You can also adjust the line style and color of the gridlines in this dialog box.

Configure Sensor Functions

The best way to set up Logger *Pro* for a particular sensor is to open an experiment file. Logger *Pro* comes with experiment files for each Vernier sensor and for the books *Physics with Computers*, *Biology with Computers*, *Chemistry with Computers*, *Physical Science with Computers*, *Real Time Physics*, and *Tools for Scientific Thinking*. All of these books are available from Vernier Software. The files load an appropriate calibration, set data collection parameters, and prepare Logger *Pro* for experiments with that sensor. Even if you want to use your own custom configuration, these files are good starting points.

Open an experiment file

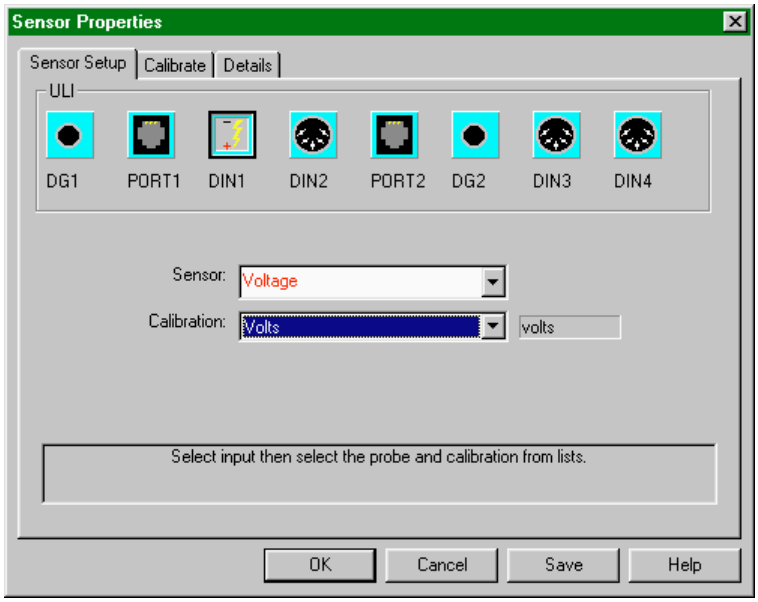
Choose Open from the File menu. Initially you will see a list of folders corresponding to the various books, the tutorials, and specific sensors. Choose the experiment file from the scrolling list that matches your sensor and application.[2] If you are not working from one of the Vernier books, we suggest that you open an experiment file listed by the sensor name. Logger *Pro* is now ready to acquire data with the selected sensor.

Perform a complete configuration

To set up Logger *Pro* for a particular sensor and experiment without an experiment file, or to add additional sensors to that supported by an existing experiment file, you will need to specify the sensor, input, and calibration file to be used in the Sensor Properties dialog. As an example, here is the way to configure Logger *Pro* for a temperature sensor. Calibration instructions follow the initial setup.

- Attach the sensor to a physically compatible port.
- Choose Sensors… from the Setup menu or click on the interface icon in the toolbar. ( or )

You will see this dialog box if you are using the ULI[3]; if instead you are using a Serial Box Interface only two DIN inputs will be visible.



[2]You may need to navigate through the directory structure of your hard disk to find the experiment files. If the Logger *Pro* Preferences are properly set you will immediately see the experiment files when you choose Open.
[3]If you are using an original ULI with a clear plastic cover, the DIN3 and DIN4 inputs will not appear.

Next,

- Click on the port to which you attached the sensor. For example, DIN1 if you attached the temperature probe to that input.
- Choose the sensor name from the Sensor scrolling list.
- Choose the desired calibration file from the Calibration scrolling list. Some sensors have several possible ranges or units choices. In most cases you will use the default calibration.

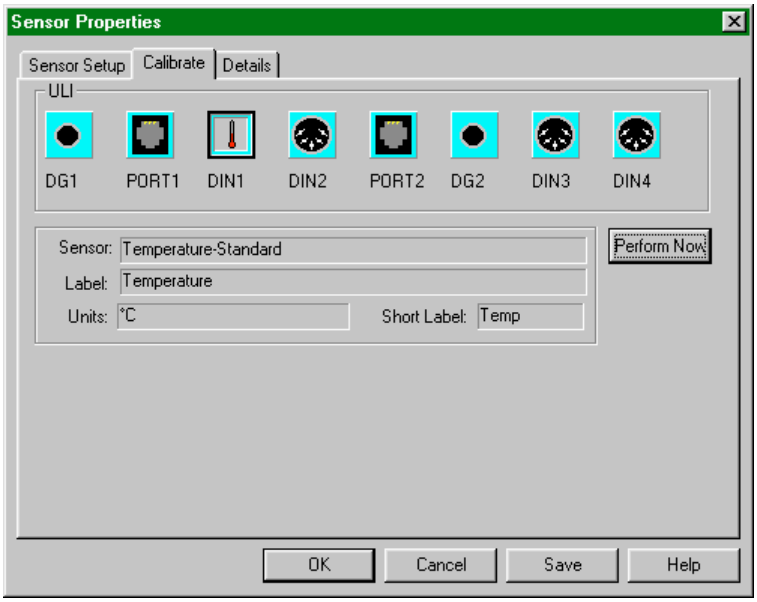
In most cases you do not need to manually calibrate, for the supplied calibration will be adequate. If you do not need to perform a new calibration for the sensor, click on OK. You are ready to acquire data. In cases where you do want to calibrate a sensor for additional accuracy, follow the instructions immediately below.

Calibrate a sensor

To calibrate a sensor you must have another way of measuring the sensor quantity. For instance, with temperature sensors you will need a separate thermometer as well as water baths of different temperatures.

To perform a new calibration,

- choose Sensors from the Setup menu if the Sensor Setup window is not already open.
- Click on the Calibrate tab at the top of the resulting dialog box.



- Click on the input or inputs to be calibrated. The selected inputs will be outlined in black.

First calibration point

- Click on Perform Now.
- Allow the sensor and the thermometer to stabilize at the first calibration temperature. You can determine this by waiting until the input readings stabilize. The input readings are the raw voltage signals from the sensor, and it is the relationship between the voltage and temperature that is being determined by this calibration.
- Read the thermometer, and enter the reading in degrees into the Value 1 field.
- Click on Keep.

Second calibration point

- Move the sensor and thermometer to the second bath and allow them to stabilize at the second calibration temperature.
- Enter the thermometer's reading in degrees into the Value 2 field.
- Click on Keep.

Save calibration

You may want to save the calibration result for later use.

The calibration information is most easily saved by saving an experiment file. The calibration information, along with all other Logger *Pro* settings, is loaded when the experiment file is opened. *We recommend that you use the experiment file method of saving calibration and experiment setup.*

If the calibration should be generally available any time a user selects that sensor in the Sensor Setup dialog, then save the calibration separately by clicking on the Save button.

- Click on Save to record the calibration to disk for later use, or click on OK to use the calibration only temporarily.

Calibration files are saved to the calibration directory set in the Logger *Pro* preferences.

Remove a sensor

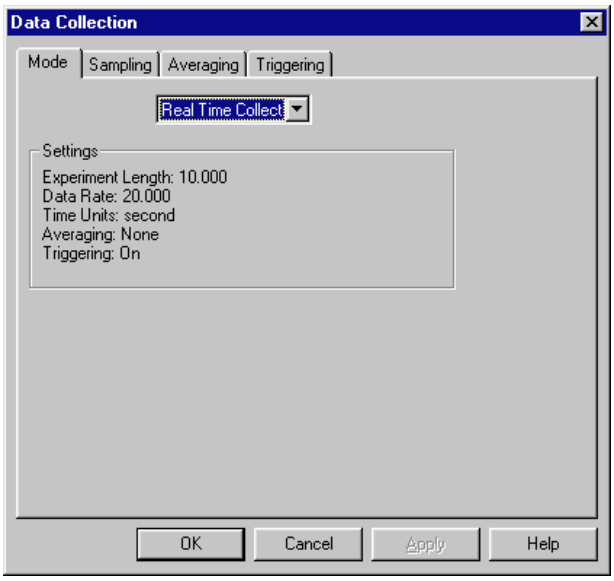
To remove a sensor from a configuration so that data are no longer collected from the input, choose Delete Column → (sensor name) where sensor name is the sensor you want to remove. You can also click on the Sensor Setup button  , then click on the input to be freed, and choose *None* from the sensor list.

Configure Data Collection Options

The easiest way to configure Logger *Pro* for a particular data collection mode is to open the appropriate experiment file. Experiment files for all compatible sensors and common data collection modes are supplied with Logger *Pro*. You can also configure Logger *Pro* manually. Instructions for manual configuration follow.

Collect data in real time

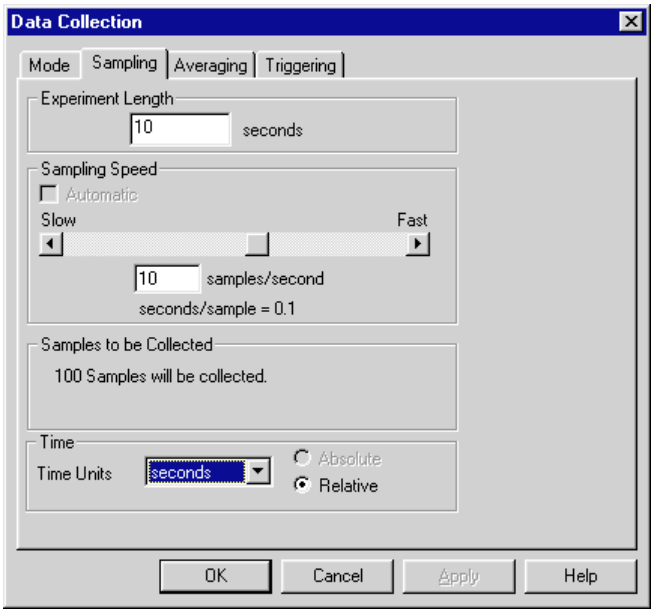
Choose Data Collection from the Setup menu. You will see this dialog box.



Select Real Time Collect from the scrolling list. In this mode data are collected continuously at the rate indicated and for the time interval set on the Sampling tab. To modify these settings, click on the Sampling tab.

Collect data repeatedly

To start new data collection runs repeatedly, select Repeat from the drop down menu. Logger *Pro* will collect a data run, pause for a moment, and then collect another run, overwriting the previous run. To stop data collection, click on the Stop button on the Toolbar. If you miss the end of a run you want to keep and Logger *Pro* starts taking data again, click on stop, then choose Undo Collect from the Edit menu to return to the previous run.



Set sampling speed (data collection rate)

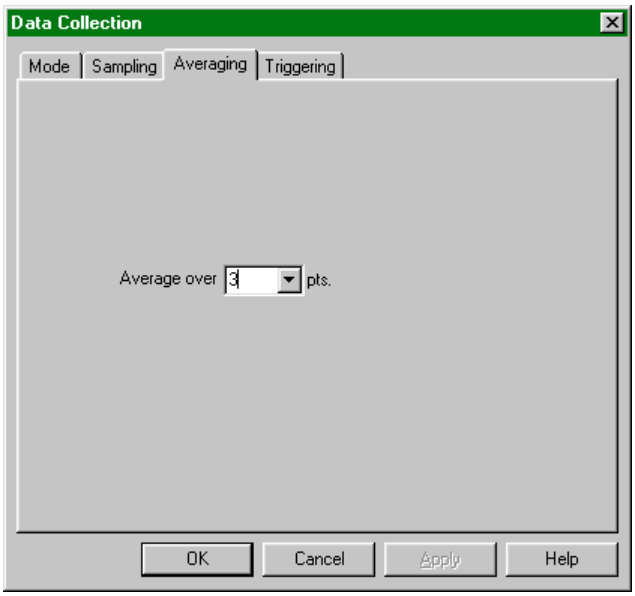
In the Data Collection Sampling tab set the time units you want and the Sampling Speed, *i.e.*, the number of points collected each second, minute, or other time interval. Sampling speed is a trade-off; too fast a speed yields unwieldy data sets, while too slow a collection rate will miss important experimental details. Logger *Pro* can collect at most 30,000 points in each input channel.

Set experiment length

Set the total time of data collection for Real Time Collect, Repeat and Selected Events modes in the Data Collection Sampling tab. You can also set the experiment length by changing the maximum time axis label to the desired value.

Set time units

To set the units used on the time axis, choose between hours, minutes, seconds, and milliseconds in the drop down menu.



Set averaging

The setting on the Averaging tab determines how many measurements will be taken for each reported point. For example, if the sampling speed is 10 samples/second and the averaging is set to 5 points, readings will be taken 50 times a second (evenly spaced in time) and 5 will be averaged to yield a single data point. Click OK to enter your settings. Only analog sensor readings can be averaged. Digital readings such as from the Motion Detector cannot be averaged.

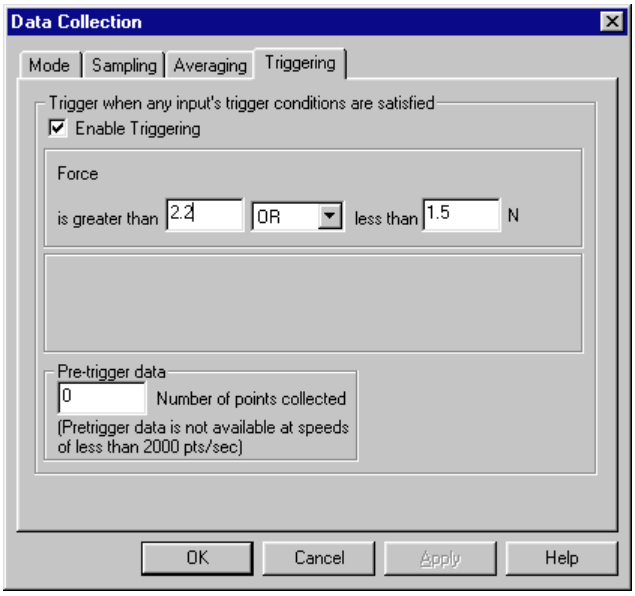
Smooth existing data

You can define a new, smoothed data column as a function of an existing column using the smooth( ) function. Choose New Column → Formula, enter a name, click the definition tab, and in the equation field enter **smooth(*"column name"*)** where *column name* is the name of the existing data column. Click OK to create the new column. Smoothing differs from averaging in that smoothing acts on an existing data column and does not reduce the number of data points.

To change the number of points used in smoothing choose Options in the Experiment menu. The subsequent dialog box allows you to vary the amount of smoothing. Excessive smoothing will obscure details in the data.

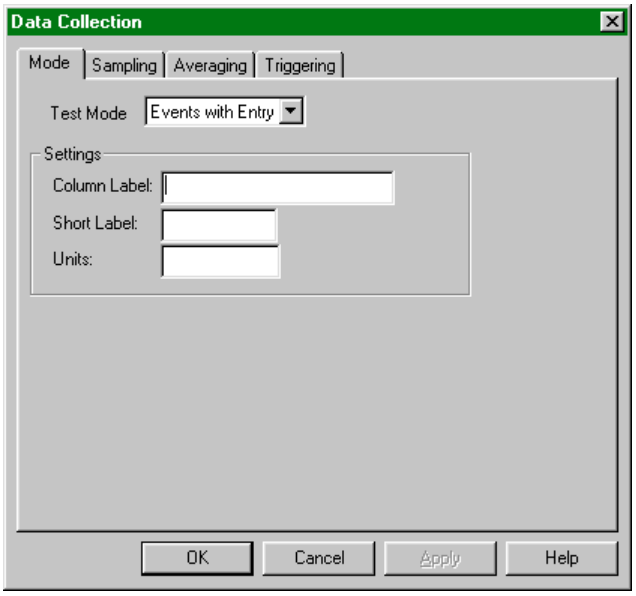
Trigger data collection

The Triggering tab of the data collection dialog allows you to set trigger conditions for data collection. When triggering is enabled in the checkbox and the Collect button clicked, *Logger Pro* waits until trigger conditions are met to collect data. If multiple sensors are in use, data collection will begin when the trigger condition is met on any *one* of the inputs. Only analog sensors can be used for triggering.



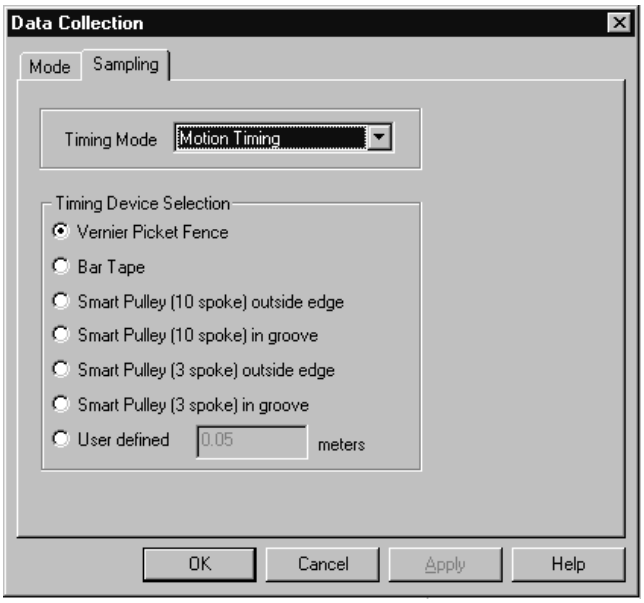
Collect data point by point (prompted)

To collect discrete data points rather than a steady stream of data, choose Data Collection from the Setup menu. Choose either Events with Entry or Selected Events from the drop down menu. In either mode, after the Collect button is clicked a Keep button appears. A data point is recorded whenever the Keep button is clicked; in addition if the mode is Event with Entry you are prompted to enter values for a new data column. For example, you might enter a volume, concentration, or trial number. The labels for the prompted column are entered in this dialog box.



Collect photogate data

To collect photogate or Smart Pulley data, choose Data Collection from the Setup menu. Choose Photogate Timing from the drop down menu on the Mode tab. It is not necessary to set any inputs using the Setup Sensor dialog. The photogate mode supports seven methods of collecting data. To see these modes click the Sampling tab:



The available modes are: Motion Timing, Gate Timing - One Gate, Gate Timing - Two Gates, Pulse Timing, Collision Timing, Pendulum Timing, and Gate and Pulse Timing. Each mode is described below. The diagram following these descriptions will help you visualize the various modes.

Motion Timing

The Motion Timing mode uses a photogate or Smart Pulley connected to the digital input DG1 only. During operation, times are recorded as leading opaque edges of a "picket fence", bar tape, or a pulley spoke pass through the photogate beam. These times are displayed in a data table. More importantly, if you enter the distance between the leading edges of the opaque bands in the Length of Object field, the program can analyze the times, and calculate velocities, displacements, and accelerations.

When a picket fence or bar tape is used, the width of each of the bands (d in the figure above) should be at least 0.5 cm. The distance between the leading edges should be at least 3 cm or larger if the picket fence is to be moving rapidly (for example in a free fall experiment). A closer spacing can be used if the object will be moving slowly; for example, on an air track glider.

Gate Timing - One Gate

This mode uses one photogate connected to DG1. The timing will begin when this photogate is first blocked. The timing will continue until the photogate is unblocked. The duration of the interruption is thus timed. If the length of the object is entered in the Length of Object field, the velocity is calculated.

Gate Timing - Two Gates

Gate Timing with Two Gates works with photogates connected to DG1 and DG2. It is assumed that the photogates will be interrupted in sequential order. The time measured at each photogate is reported in a

different column in the data table. If the length of the object is entered in the Length of Object field, the velocities are calculated.

Pulse Timing

Pulse Timing refers to the measurement of the time from the blocking of one photogate until another photogate is blocked. The timing will begin when the photogate in DG1 is first interrupted. It will continue until the photogate in DG2 is interrupted. If the length of the object is entered in the Length of Object field, the velocity is calculated.

Collision Timing

The Collision Timing mode uses photogates attached to DG1 and DG2. It differs from other timing modes in a number of ways. It allows both photogates to time independently and times are listed in the data table in columns, according to the gate at which they were measured. Other modes list times in columns, in order as they were measured. A data table of results measured in this mode will look like this:

Times Listed By Gate:	
Delta T1 (s)	Delta T2 (s)
0.5552	0.7872
0.4332	
3.4437	
1.0012	1.2623

For each gate, the times are listed in the order in which they were measured. In the example above, photogate #1 was blocked 4 times and photogate #2 was blocked twice.

Notice that the Collision Timing mode is similar to the Gate Timing - Two Gates mode, without any restriction on the order in which the two gates are blocked. This mode is specifically designed for studying air track collisions. It allows the study of virtually any possible collision.

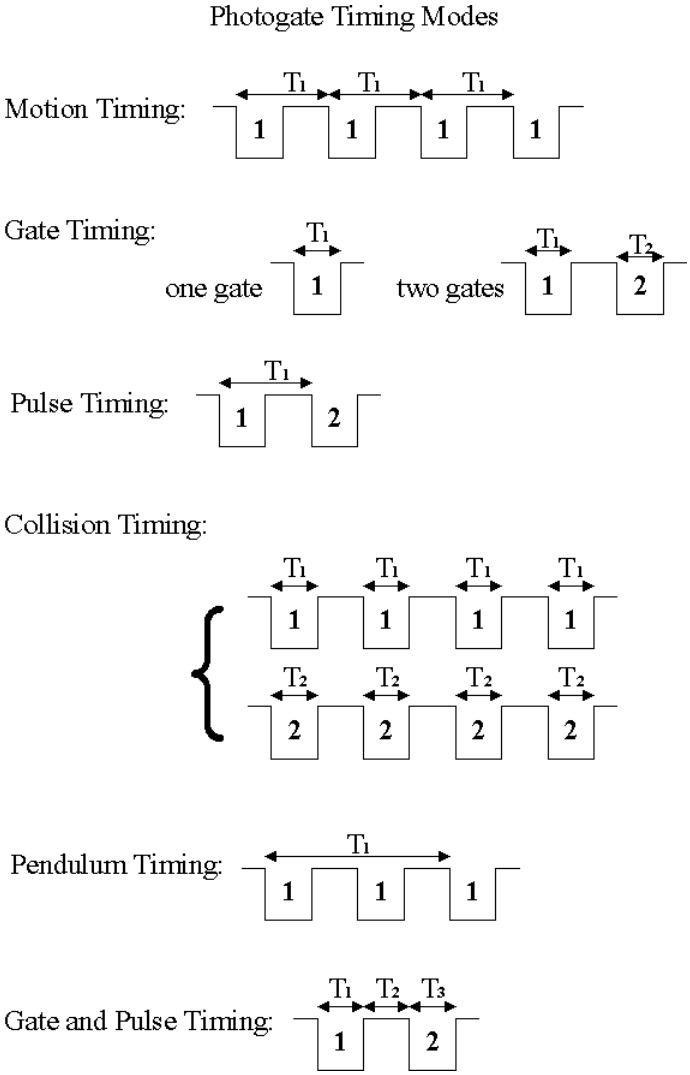
Pendulum Timing

The Pendulum Timing mode uses a photogate attached to DG1. The timing will begin when the photogate is first interrupted. The timing will continue until the photogate is interrupted twice more, so that you get the time for a complete swing of a pendulum or other oscillating object.

Gate and Pulse Timing

This mode requires two photogates. The first timing is of the duration of the interruption of the photogate #1. The second timing begins when photogate #1 is unblocked. This timing continues until photogate #2 is blocked. The third timing is of the duration of the interruption of the beam in photogate #2. If the length of the object is entered in the Length of Object field, the velocity is calculated. The acceleration is calculated from the change in speed.

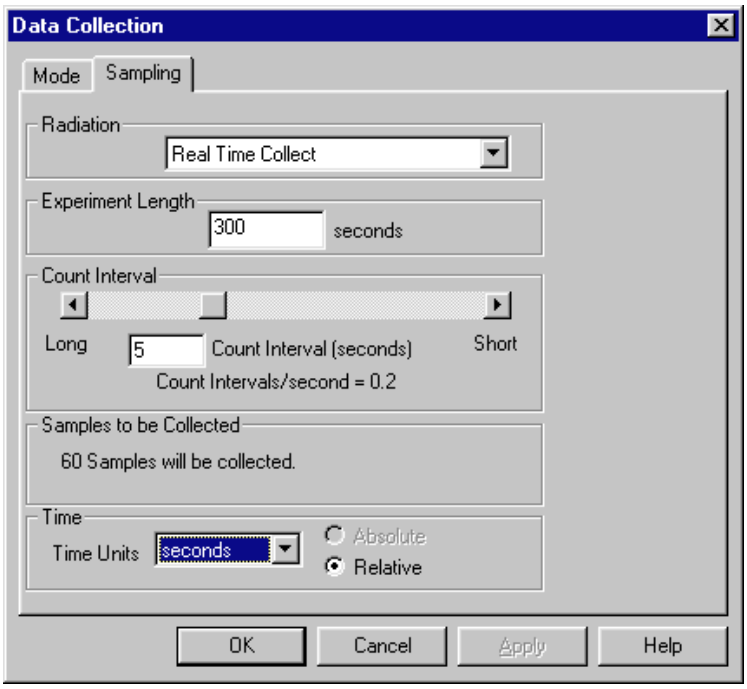
The following diagram illustrates the various photogate timing modes. For each line, the vertical axis represents the photogate state with unblocked as high, and the horizontal axis represents time.



Collect radiation data

To collect data from the Radiation Monitor or the Student Radiation Monitor, choose Data Collection from the Setup menu. It is not necessary to set any inputs using the Setup Sensor dialog. Choose Radiation Counting from the drop down menu on the Mode tab. Click the Sampling tab to set the experiment length and the length of one counting interval. Logger *Pro* will report the number of pulses received during each counting interval.

There are two Radiation Counting methods: Real Time Collect and Events with Entry, chosen on the Sampling Tab. In Real Time Collect mode Logger *Pro* will count for successive counting intervals until the set experiment length is reached. In Events with Entry, Logger *Pro* will count for successive counting intervals, but will not record a value until the Keep button is pressed. At that time an entry field will be displayed for the user to enter a value. Press Enter to complete the entry, and then Stop when the desired number of points have been collected.

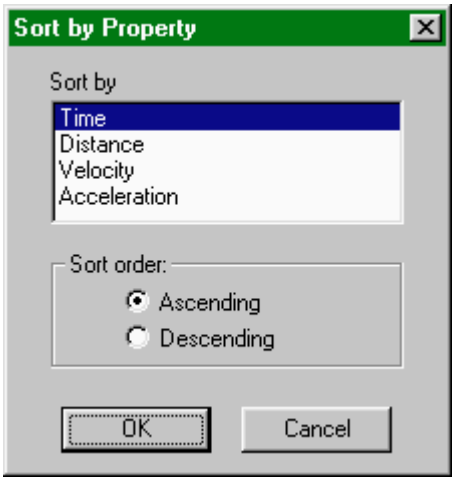


Correct entries

You can correct mistakes in the prompted column created by Events with Entry mode. First, collect any additional data required in the run. Then, click the Stop button. In the Data Table Window, click on the cell you want to change. Type the new value. Click on another window to confirm your entry, or press Enter to continue corrections in the cell below. Sensor data cannot be modified, just as a scientist never erases data in a notebook.

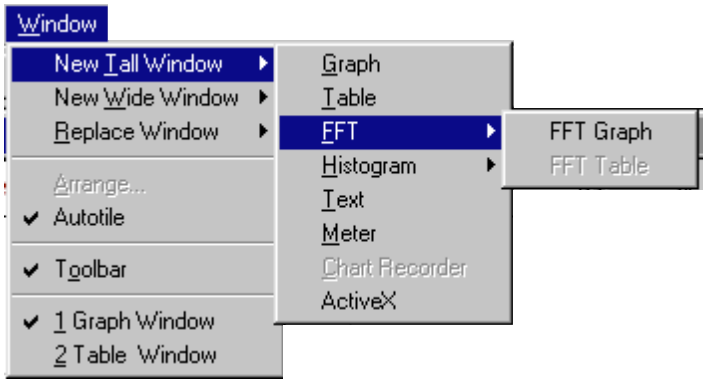
Sort data

If the column used for the horizontal axis is not in ascending or descending order the graph will not be drawn correctly when connecting lines are enabled. This can easily happen when the column consists of prompted entries. Choose Sort Data from the Data menu, choose the column by which to sort, click ascending or descending as desired, and click OK.



View Other Window Types

The Windows menu contains commands that add or replace windows to the Logger *Pro* Screen. Since each new window reduces the screen area available for the existing windows, the precise action of the window commands depends on the currently active window. New Tall Window halves the width of the current window and creates a new window of vertical orientation of the selected type. Similarly, New Window Wide halves the height of the current window and creates a wide window of the selected type. Replace Window replaces the selected window with a window of the newly selected type.



Graph

Choose New Tall Window → Graph from the Window menu. A new graph window will be created. Note that it may be more useful to create a new pane in a graph window instead since less screen area is required. See Graph Layout in the View menu of Logger *Pro* Reference for more information.

Table

Choose New Tall Window → Table from the Window menu. A new data table window will be created.

FFT → FFT Graph
FFT Table

Choose New Tall Window → FFT → FFT Graph to create a new graph window holding the FFT (Fast Fourier Transform) of the current data. Once you have created an FFT Graph, you may choose FFT Table to open a new data table window containing the numerical FFT information. Double click on either FFT window type to adjust its properties.

Histogram → Histogram Graph
Histogram Table

Choose New Tall Window → Histogram → Histogram Graph to create a new histogram window representing the current data. Once you have created a Histogram Graph, you may choose Histogram Table to open a new data table window containing the numerical histogram data. Double click on either histogram window type to adjust its properties. The bin width may be changed in the Axis Options tab of the Histogram Options dialog box.

Text

Choose New Tall Window → Text from the Window menu. A new window will be created for text entry. You can use this window for laboratory instructions, information about the experiment, or other notes.

Meter

Choose New Tall Window → Meter from the Window menu. A dialog box will open which allows you to select the data columns to be displayed in a digital meter window. Then a new window will be created containing the selected digital readouts. Double-click on the meter window to change which quantities are displayed.

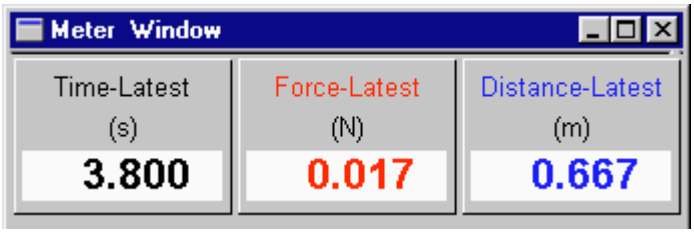


Chart recorder

This feature is not available in the current version of Logger *Pro*.

Arrange graph and data windows

After opening several different windows, the screen can get cluttered. To help organize your screen, choose Autotile from the Window menu. Autotile will fill the screen area with the open windows, making them as large as possible but keeping all in view at once.

Analyze Data

Read values from graph

Choose Examine from the Analyze menu. A legend will appear, accompanied by the numerical value at the mouse pointer position. As the mouse cursor is moved across the graph, the legend readout will change and the data table will scroll to highlight the associated time and numerical values.

If you have a meter window open and Live Readouts mode is not enabled, then the meters will also read values near the cursor location.

Display tangent lines

To draw tangent lines and read the slope of those lines, choose Tangent from the Analyze menu (or click on the tangent line button on the toolbar) and move the pointer to the place where you want the slope. A legend will appear, accompanied by the numerical value of the data and the slope of the tangent line at the pointer position.

Compare runs

Often you will want to compare two similar runs of collected data. When you get the first useful run, choose Store Latest Run from the Data menu. Now you may take additional data and the stored run will not be lost. The data will be retained through subsequent data collections, and can be displayed or hidden as desired. Stored runs are numbered sequentially. Any number of runs can be stored, and will be saved when you save an experiment to disk.

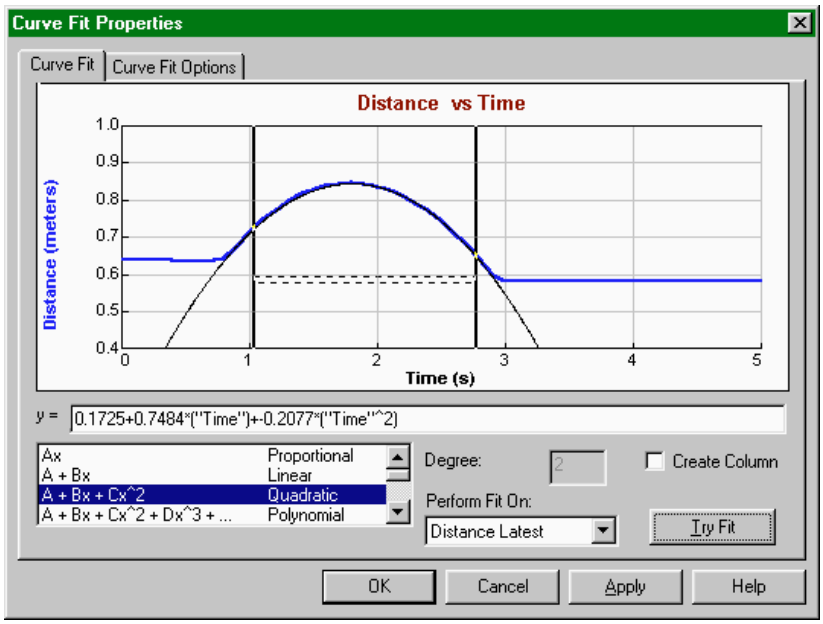
The Data menu has two more relevant functions. Hide Run will temporarily remove the selected run from the graph, and Show Run will put it back. Using these functions you can superimpose any desired set of runs.

Fit a line to data (linear regression)

To fit a straight line to your data, select the desired portion of the data by dragging across it. Next, choose Linear Fit from the Analyze menu (or click on the linear regression button on the toolbar). A straight line will be fit to the indicated data, and the slope and intercept information will be displayed in a floating box. Displayed precision can be adjust by double-clicking on the floating box to open a new dialog box.

Fit functions to data

To fit more complex functions to your data choose Curve Fit from the Analyze menu (or click on the general fit button on the toolbar). You will see the following dialog box. To fit to just a part of your data, you must first select the desired portion of the data by dragging across it.



Now choose a mathematical relation from the list at the lower left. You may need to scroll through the list to find the appropriate function. The polynomial choice also requires that you set the degree of the polynomial. Next, choose the data set you want to use from the Perform Fit On menu. Click on Try Fit to see the result. If you like, choose another function or data column for another trial fit. You can also select a different range of data by dragging across the graph region. Click on Try Fit to see the new fit. Once you have a fit that you like, click on OK to display the fitted curve on your graph. Click on Cancel to discard all fits. The Apply button will place the fitted curve on the main graph window without closing the dialog box.

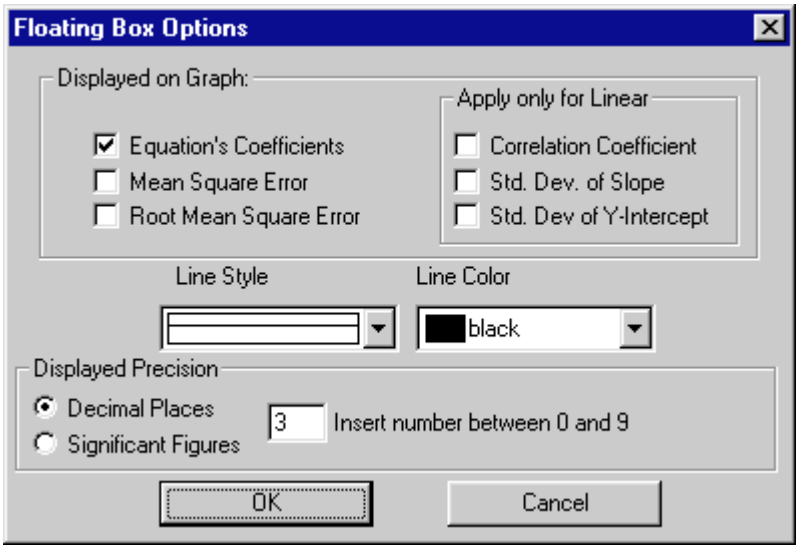
Model Data (Manual Fit)

To superimpose a function over your data, make a graph active by clicking on it once. Select Manual Fit from the Analyze menu. In the dialog box select a function. Adjust parameters as needed to fit the function to your data.

Note that poorly-chosen parameters may make the function miss the graphed region entirely. In this case it is difficult to adjust the parameters by trial and error. You may want to select parameters carefully so that the function matches the data at the y-intercept, and adjust values from there.

Change Displayed Precision of Fit Parameters

You can adjust either the number of significant digits or the number of decimal places used in displaying fit statistics and parameters. After you have completed a fit, double-click on the floating box containing the fit information. A floating box options dialog will open, allowing you to set the line color, line style, fit coefficients displayed, and their precision.



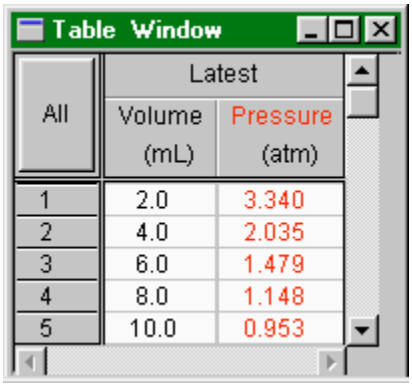
Interpolate points

To interpolate between data points, first fit a function to a range of data. Then choose Interpolate from the Analyze menu. The floating box for the curve fit will expand to show the coordinates of points along the fitted curve. Move the mouse pointer to the place you want to interpolate.

Perform an FFT

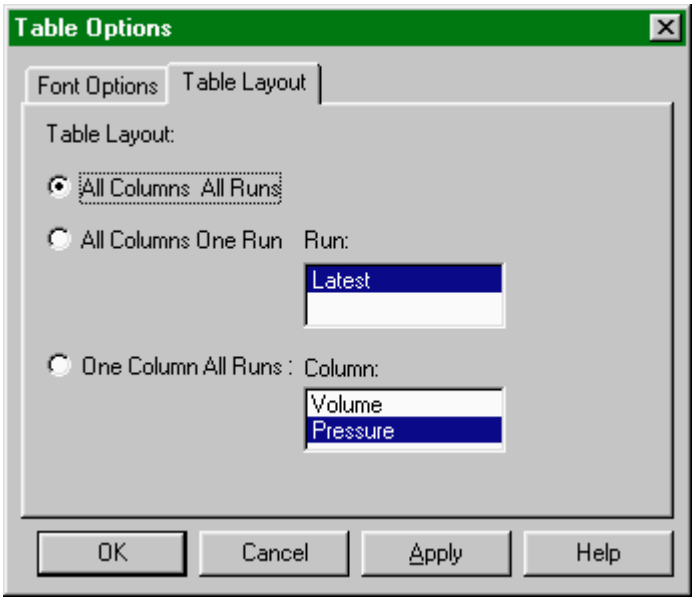
To perform an FFT on the entire data sequence, choose New Tall Window → FFT → FFT Graph from the Window menu. You can also use New Wide Window. Double click on the FFT window to adjust its parameters.

Perform Data Table Functions



Change what runs appear in the data table

You can control what is displayed in the Data Table Window. The display font can also be changed if you want to see a larger or smaller number of rows at once. Double click on the data table to change table options and click on the Table Layout tab. You will see this tabbed dialog box.

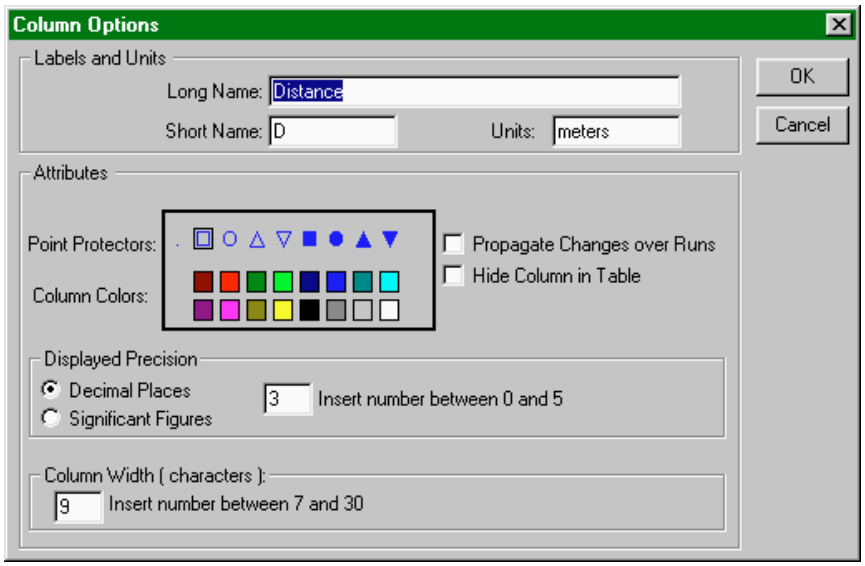


Choose the table layout you need. The choices allow you to display all columns from all runs, just a single run, or just one column from all runs. You can further control what is shown in the data table by hiding individual columns in the Column Options dialog found in the Data menu, or by double-clicking a column header.

The Font Options tab shows a dialog in which you can choose display font and size for the data table.

Change a column's name, color, width, or digits displayed

Double clicking a column heading or the Run heading will open the Column Options dialog, allowing you to change the column name, width, color, or digits displayed. Double clicking the Run header will allow you to choose a column from a list; double clicking a column header directly will take you to the Column Options dialog for that column.



In the Column Options dialog you can change the column's name, color, decimal places displayed, and width. If you click in the box for Propagate Changes, all runs for that column will be affected. Hide Columns will conceal the column in the data table.

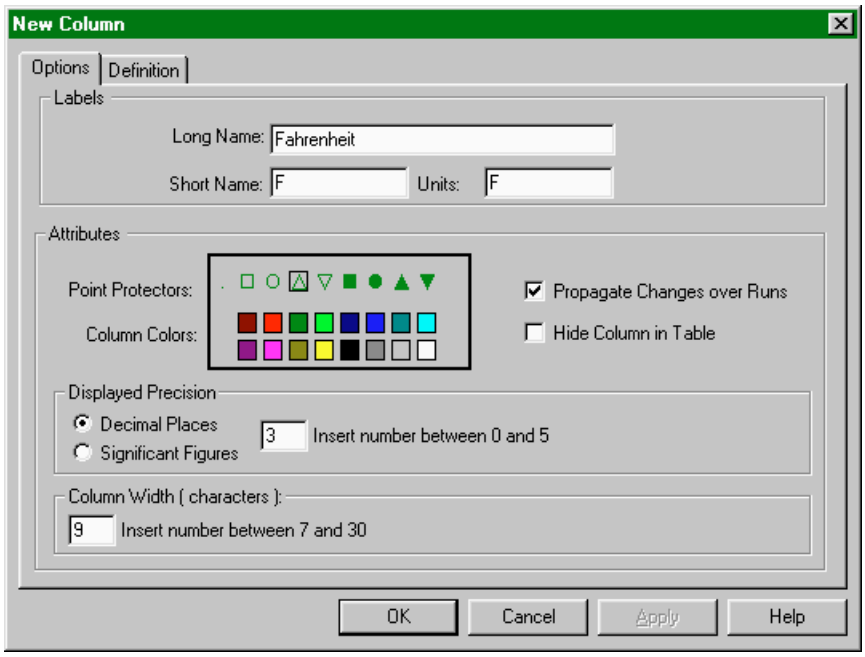
Calculate new values from raw data (new columns)

As Logger *Pro* gathers data from a sensor, the data table fills in with time and sensor readings. You can define rules for columns calculated from the sensor readings much like you enter formulas in a spreadsheet. The definition can be entered either before or after the data are collected. These new columns can be graphed just like any other column, even as data are being collected. The calculated columns can be used for a variety of purposes, including graphing calculated data or data entered from the keyboard. These are described in turn below.

Calculated data columns—an example

As an example, let us convert temperatures measured in degrees Celsius to degrees Fahrenheit. To get °F, we will need to multiply the raw data from the Temperature Sensor, in °C by 9/5 and then add 32.

First, choose New Column from the Data menu. You will see this dialog box, but without the entries you are about to make. Click on the Options tab to be sure this pane is on top.

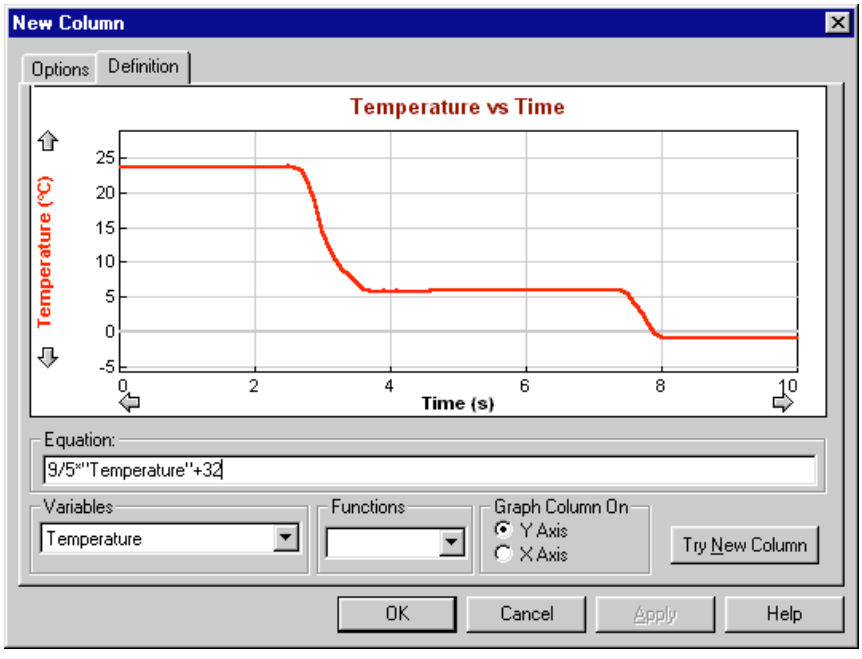


Labels

To give this example column appropriate labels, enter Fahrenheit in the label field and degrees F in the units field. The short label is used in places where there isn't room for the whole name; here, F would be a good choice.

While here you can also make other choices for the new column such as color for graphing.

Next click on the Definition tab to see the rest of the dialog box and to complete the column creation process.



Equation

The Equation field is where you will build the formula that defines the new column. In this example of finding °F, we need to enter in the formula field 9/5*“Temperature”+32. (Because of the order of arithmetic operators, no parenthesis are needed, but you can use parenthesis as desired to make the formula more readable.) To avoid typographical errors, choose variable and function names from the Variable and Function lists rather than typing them in.

Graph Column On

The newly calculated column can be graphed either on the y- or the x-axis. In this case the default of the y-axis is appropriate. The new column will replace whatever had been graphed on its column.

Try New Column

When you click on the Try New Column button, the calculation will be performed and plotted if some data have already been taken. If you like what you see, click on OK to return to the main graph window which will include the calculated plot.

Enter data manually

To enter a data column manually, choose New Column → Manual from the Data menu. Enter a label, short label, and units in the fields provided. Choose a color and point protector as desired.

The data table will contain a new, blank column. Click on a cell to type in values.

To paste a column of numbers from the clipboard into a Manual Entry column, click the first cell, then choose Paste from the Edit menu.

You must have already collected data from a sensor to enter data manually. The maximum number of manually-entered points is limited to the number of points already collected from a sensor.

Copy data to a spreadsheet or graphing program

To copy all or part of your data in numerical form, select the desired portion of the data table; you can select it all by choosing Select All from the Edit menu. Next, choose Copy from the Edit menu to place the data on the clipboard. Now switch to the destination application.

Once you have the receiving spreadsheet ready to accept the data, choose Paste from the Edit menu. The data will appear in the application. You do not have to quit Logger *Pro* to switch to another application.

Save and Print Data

Save data, calibration and configuration

You can save your experiment to disk by choosing Save from the File menu. The experimental configuration, including data, calibrations, column definitions and window types will be saved. A standard save file dialog box will appear. Choose a location for the file, enter a descriptive file name, and click on OK.

Saving a complete configuration in this manner is an excellent way to record an experiment so you can later reproduce or extend the work in identical conditions. In addition instructors can save a configuration for students to use later; students then do not have to perform any configuration or calibration and can immediately begin to collect data.

To save only the calibration information so that it is available when manually configuring Logger *Pro*, open the Sensor Setup dialog box. Then click on the input corresponding to the desired calibration and click on the Save button. Enter a name for the calibration file of eight characters or fewer, and click on OK. The file will be saved to the default calibration folder set in Logger *Pro* Preferences.

Paste data into other applications

Select the data and choose Copy from the Edit menu to place the data on the clipboard. Paste the data into the receiving application, or to a text editor to create a text format data file.

Retrieve an experiment

Choose Open from the File menu, and navigate to the folder containing the desired file. Click on the file name. Since experiment configuration is stored in a Logger *Pro* file, on loading the file any current configuration will be overwritten.

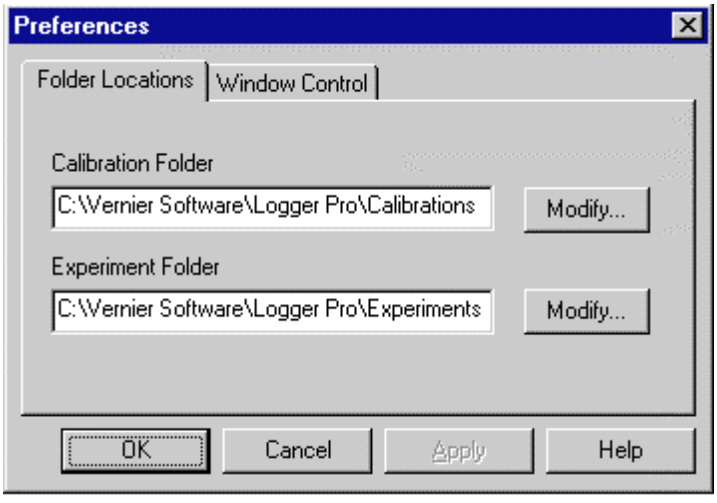
Print a graph or data table

To print a graph or data table, make the graph or data table the active window by clicking on it, choose Print from the File menu, and respond to the resulting dialog box.

Set default file locations

The default location of calibration and experiment files can be set in Logger *Pro* preferences. While experiment files may be stored anywhere, Logger *Pro* will first look in the default experiment file folder. Calibration files, both those saved by users and those supplied with Logger *Pro*, must be within the default calibration folder.

To set default file locations, choose Preferences from the File menu. You will see this dialog box.



Click on the appropriate Modify button to change either the default calibration or experiment file folder. Choose the desired folder in the subsequent dialog, and click OK.

Teacher's Guide

Software Installation

Required materials

To use Logger *Pro*, you must have the following equipment:

A computer:

- A PC running Windows 95/98, Windows NT 4.0 or Windows 3.1x with at least 16MB RAM, at least a 486 processor, and an unused serial port with a 16550 UART chip. If the computer's mouse is connected to a serial port, this means the computer will need two serial ports. (Please contact us for further details.)

  or:

- A Power Macintosh or Power PC running System 7.6.1 or newer with at least 16MB RAM, 10 MB of hard disk space, and an unused modem or printer port. Macintosh computers lacking a serial port will require a USB-to-serial adapter.

An interface, which can be either:

- A Universal Lab Interface (ULI) with a 9-volt power supply and an interface cable

  or:

- A Serial Box Interface with a 9-volt power supply and an interface cable

and at least one sensor:

- A temperature sensor or a Motion Detector are good choices for initial testing of Logger *Pro*. A Voltage Probe is included with the ULI and Serial Box Interface and can also be used.

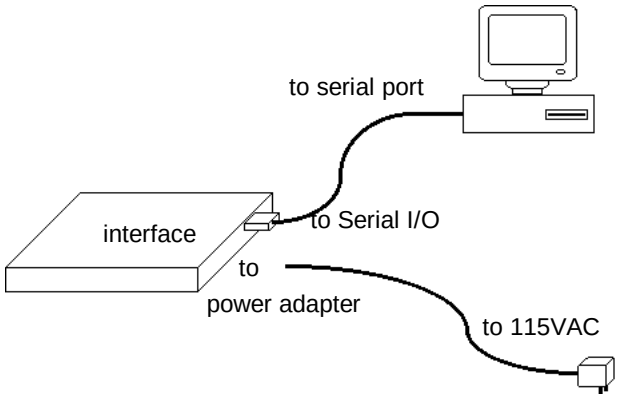
All of these items (except computers) are available from Vernier Software, 8565 S.W. Beaverton-Hillsdale Hwy., Portland, Oregon 97225-2429, (503) 297-5317, email: info@vernier.com, web site: www.vernier.com.

Appendix C discusses the differences between the ULI and the Serial Box Interface, and *Appendix D* lists sensors compatible with Logger *Pro*.

Initial setup

Before turning on your computer, you should set up the Universal Lab Interface (ULI) or Serial Box Interface with a sensor. The interface should be placed near the computer. First connect the interface cable to the interface. Then attach the cable to any unused serial port[4].

[4]On the PC, the connector on the computer may be either a 25-pin plug or a smaller 9 pin connector. An adapter is supplied with the interface to make the appropriate connection to your computer.



Interface Connections

Next, plug the 9-volt power supply into the matching receptacle on the interface and into a source of 60-Hz, 115-VAC power.

Software installation Macintosh

To install Logger *Pro* on a Power Macintosh, follow these steps:

- Place the Logger *Pro* CD in the CD-ROM drive of your computer.
- Double-click the icon *Install Logger Pro* and follow the instructions on screen.

Software installation Windows 95/98/NT 4.0

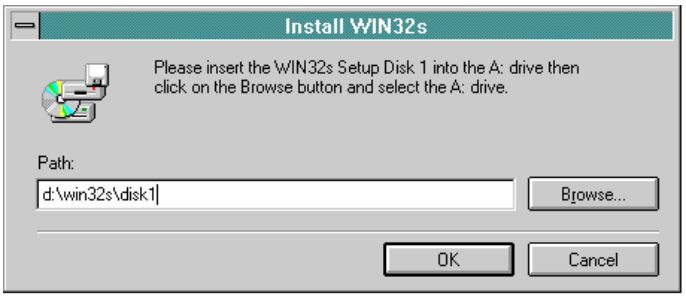
To install Logger *Pro* on a computer running Windows 95/98/NT 4.0, follow these steps:

- Place the Logger *Pro* CD in the CD-ROM drive of your computer.
- If you have Autorun enabled, the installation will launch automatically, otherwise choose Settings → Control Panel from the Start menu. Double click on Add/Remove Programs. Click on the Install button in the resulting dialog box.
- The Logger *Pro* installer will launch, and a series of dialog boxes will step you through the installation of the Logger *Pro* software. You will be given the opportunity to either accept the default directory or enter a different directory.

Software installation Windows® 3.1x

To install Logger *Pro* on a computer running Windows 3.1x, follow these steps:

- Place the Logger *Pro* CD in the CD-ROM drive of your computer.
- From the Program Manager choose Run from the File menu. In the Command Line Field type d:\setup or e:\setup depending on the CD-ROM drive used in your computer, and click OK.
- The Logger *Pro* installer will launch, and a series of dialog boxes will step you through the installation of the Logger *Pro* software. You will be given the opportunity to either accept the default directory or enter a different directory.
- In order to run Logger *Pro* on a Windows 3.1 machine, Microsoft WIN32s software must be installed. If WIN32s is not installed on your machine, you will be prompted with the following screen:



- Make sure that the path is pointed to "disk1" on the Logger Pro CD.

- Click OK and follow the remaining directions.

Note: If your computer does not have a CD-ROM drive, please contact Vernier Software to request a copy of Logger *Pro* on floppy disk

Software installation (network)

If your computers are served software from a central file server on a network, you can install Logger *Pro* on the server.

Additional suggestions for configuring a network server to work with Logger *Pro* can be found in *Appendix B.*

Ideas for using Logger *Pro* in the classroom

How to use the tutorials

The tutorials, printed separately from this manual but included with Logger *Pro*, can also be used as a student introduction to the program. The first two, Temperature and Motion, are parallel introductions to Logger *Pro*. The former is designed for all students, and the latter for students who will use the Motion Detector. The remaining tutorials extend the two introductory tutorials to more advanced use, including data analysis and curve fitting. They might be used as individual class assignments or could be made available for reference as students begin using Logger *Pro*.

Experiment files are important!

Experiment files contain information about the particular configuration of Logger *Pro*, including the number of graphs, what is plotted on each axis, the data collection rate and mode, what sensors are connected to inputs, and the calibration information used. In other words, a complete data collection environment can be saved for later use. If a custom calibration is performed, that information is saved in the experiment file without requiring a separate calibration file. Once an appropriate experiment file is loaded and the interface and sensors connected, you are ready to collect data.

Many teachers find that they spend less time teaching computing and more time teaching science if they make use of experiment files. Some curricular packages include experiment files for Logger *Pro*, so that students can load an indicated file and be ready to take data in a mode appropriate for the experiment. You can also create your own experiment files for use with custom laboratory experiments. See the section below on creating your own experiment files.

Experiment files included with Logger *Pro*

Logger *Pro* comes with an extensive set of experiment files. The first set is designed for typical experiments done with each Vernier sensor. These files are in folders corresponding to the sensor name. The next set, found in the Tutorials folder, are for the tutorials earlier in this manual. The remaining six sets are keyed to the specific experiments found in the Vernier publications of ready-to-use classroom experiments.

Protecting experiment files

When experiment files are installed on individual computers, it is important to keep the files from being unintentionally altered. The open-file dialog box includes a check-box marked Open as Read Only. When the check-box is marked (the default), a file is opened as read-only. A read-only file can be used normally, but it cannot be saved using the Save command. The save button on the toolbar and the Save command are disabled, and if the user clicks Save As…, the file name field is blank. The file can be saved under any name, but if the name matches an existing file an extra confirmation dialog will be presented.

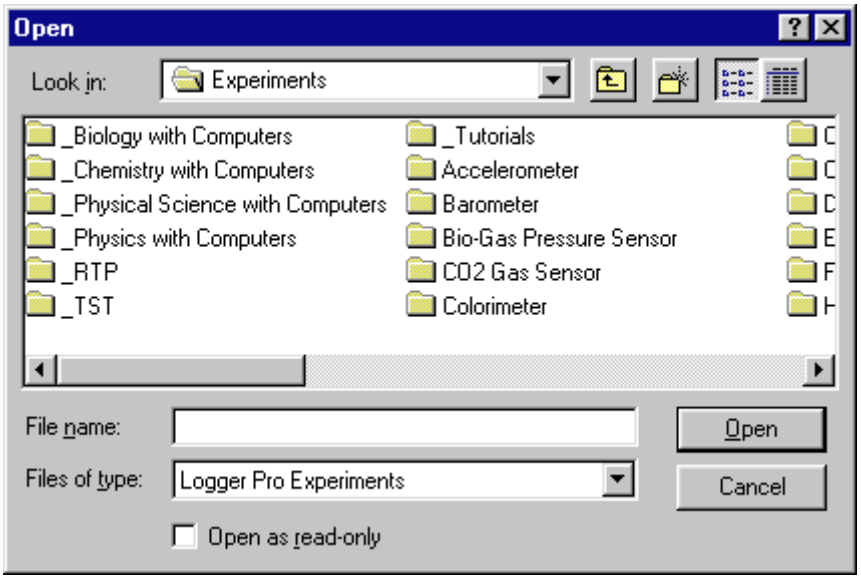
If you intend to make permanent changes to an experiment file, clear the check-box, open the file, and make the desired changes. Save your file.

Sources of experiments for Logger *Pro* from Vernier Software

- *Biology with Computers*, by David Masterman, and Scott Holman 30 experiments.
- *Chemistry with Computers*, by Dan D. Holmquist and Donald L. Volz, 30 experiments.
- *Physical Science with Computers*, by Donald L. Volz and Sandy Sapatka, 41 experiments.
- *Physics with Computers*, by Kenneth Appel, John Gastineau, Clarence Bakken, David Vernier, 34 experiments.

- *RealTime Physics*, by David Sokoloff, Ronald Thornton and Priscilla Laws, 12 experiments in mechanics. (RTP folder)
- *Tools for Scientific Thinking*, by Ronald Thornton and David Sokoloff. Experiments in Motion and Force; Heat and Temperature, Sound. (TST folder)

The experiment files for these books are found in the Experiments folder of Logger *Pro* with names beginning with an underscore to move them to the head of the file list:



Calibration files

Although creating an experiment file will save calibration information, you can also save sensor calibration information separately. Your custom calibration will then be among those offered in the sensor setup dialog.

Logger *Pro* includes calibration files for the Vernier Software sensors listed in *Appendix C*. For most sensors these calibrations are all you will need. A few sensors, such as for dissolved oxygen and colorimetry need individual calibration; the force and pH sensors can be calibrated for higher-accuracy results. The calibration procedure is described in the reference section.

Creating an experiment file

To create your own experiment files, you will need to set up Logger *Pro* as appropriate for your experiment. You may want to start with an existing experiment file that is close to the configuration you need.

- Configure or confirm that Logger *Pro* is properly set for the sensors you will use, including any calibration information.
- Set the data collection mode, period, and rate as needed.
- Define any new columns you need.
- Set up the graphs as desired. Create the number of graphs, the scaling, and what is plotted for your experiment.
- Consider entering an Experiment Note (choose About *filename* from the Help menu, where *filename* is the experiment file name) to give preliminary instructions which will be displayed when the file is first opened.
- Consider adding an explanatory or instructional text window which will be visible during data collection. (Choose New Window → Text)

- Test your setup by performing a trial experiment, and make changes as needed.
- If you do not want to save your example data with the experiment setup, clear the data by choosing Clear All Data from the Data menu.
- Choose Save from the File menu. Enter a descriptive file name, and save the file.

To use the file later with students, place a copy of the file in the default experiment file directory specified in the Logger *Pro* preferences file.

Customizing Logger *Pro*

Certain settings of Logger *Pro*, such as the default location of files and the statistics presented in curve fits, which you are unlikely to change every session, can be stored in a preferences file. See Preferences under the File menu. The file must be stored in the same directory as Logger *Pro*. If you are using a network, be sure you have sufficient privileges when you store your preferences. Consult *Appendix B* for detailed network suggestions.

Using Logger *Pro* on a network

Using Logger *Pro* on a network is similar to using it on a stand-alone computer. However, the benefits of network access to Logger *Pro* include the need to install only one copy of the software, further protection of experiment and calibration files from accidental change, and reduced hard disk requirements on the local computers. For details, see the discussion in *Appendix A.*

Using Logger *Pro* on stand-alone computers

During the installation process above, a directory will be placed on your hard disk which includes Vernier calibration files and experiment files. The preferences file will initially use these directories as default.

Sensors to use with Logger *Pro*

Appendix C lists the sensors compatible with Logger *Pro*.

Logger *Pro* Reference

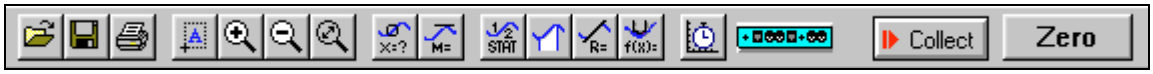
Keystroke Equivalents

Logger *Pro* supports standard keystroke equivalents for common menu commands. On PC hold down the Control key (it may be labeled Ctrl on your keyboard) and the appropriate letter key. On Macintosh computers hold down the Command key while striking the appropriate letter key.

command	**keystroke**
Save	Control/Command S
Open	Control/Command O
Print	Control/Command P
Autoscale	Control/Command A
Undo	Control/Command Z
Copy Graph	Control/Command G
Copy	Control/Command C
Cut	Control/Command X

Paste	Control/Command V
Replay	Control/Command R
Adjust Sampling	Control/Command M
Adjust Averaging	Control/Command E
Adjust Triggering	Control/Command T

Toolbar

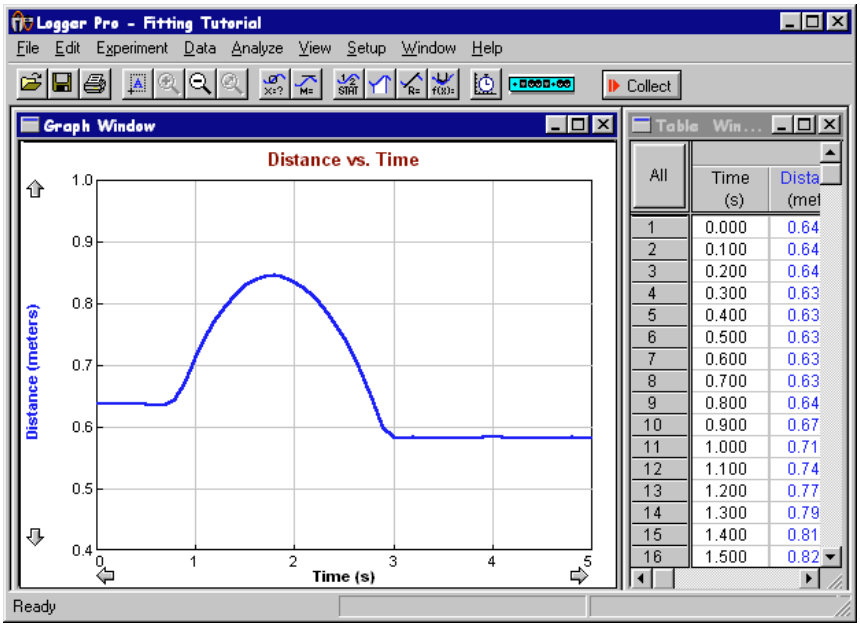


The toolbar provides quick access to some common functions. From left to right, these are Open, Save, and Print. The next group includes Autoscale, Zoom In, Zoom Out, and Undo Zoom. The third group toggles Analyze, Tangent, Statistics, Integral, Line Fit, and Curve Fit. Next, the stopwatch button opens the data collection dialog box. The icon showing an interface selects the Sensor Setup dialog, and the Collect button initiates data collection. If present, the Zero button resets an analog sensor reading to zero.

You can quickly see what a tool does by positioning the pointer over the button for a moment; a legend will appear.

Cursor Controls

You can change the graph appearance and behavior through a number of “hot spots” on the Graph Window and the Table Window. The screen below shows some of these functions.



These areas of the Graph Window are active to cursor control:

Graph title

Click on the graph title to obtain a dialog box in which you can modify or remove the graph title.

Tick mark labels

You can click on the minimum or maximum axis numeric labels and type in a new value. The axis of the graph will change accordingly. When the independent variable is time the right-most time value will also determine how long data are collected.

Axis labels

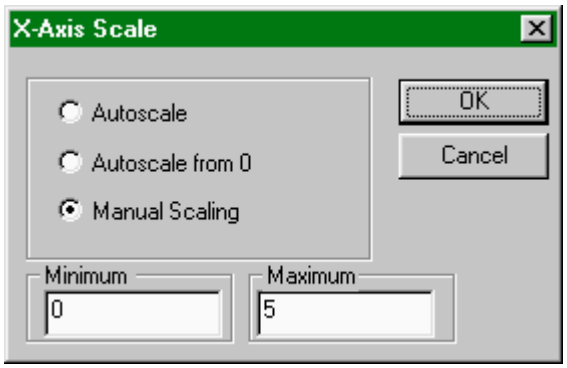
Clicking an axis label will open a dialog box that allows you to choose what is plotted on that axis.

Scroll arrows

You can scroll the viewing region of the graph with the scroll arrows. The axis limits will change, but the interval displayed by each axis will remain the same.

Axes

To change the scale of one axis at a time, click on it. A dialog box will open, allowing you to control the scaling of that axis.

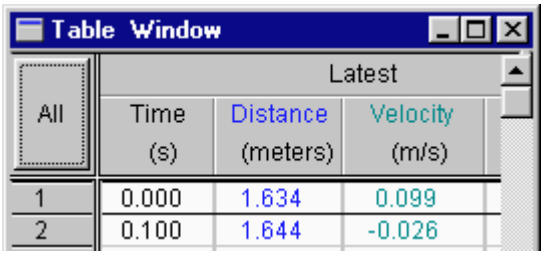


Graph options

Double-click on a graph to change several properties at once. The Graph Options dialog will appear, allowing you to change scaling, labels, or plot style. More details can be found under Graph Options in the Logger *Pro* Menus section.

Selecting a graph

If there is more than one graph on the screen, any commands that affect graphs will change only the selected graph. To select a graph, click on it. A border will appear around the graph to indicate that it is selected.



The Table Window also responds to clicks:

Select All/None

Clicking the All/None button will alternately select all data and no data.

Column properties

Double-clicking the row numbers will open the Table Options dialog. There you can change the font used and choose which columns will be displayed.

Column options

Double clicking the Run Heading (Latest, Run 1, and so forth) will open a dialog box holding a list of columns. Select a column, click on OK, and the Column Options dialog for the chosen column will open. Double-clicking a specific column header will open its Column Options dialog directly. You can find more details about Column Options under the Data menu details below.

Column order

To rearrange the order of displayed columns, drag the column header to the desired position.

Edit cell contents

Only cells in manually entered columns or prompted columns collected in Events with Entry mode can be edited. Click the cell to be changed. Type in the new value, and press enter.

Logger *Pro* Menus

Apple menu

(Macintosh only)

About Logger Pro…

Choose this item to display information about Logger *Pro*. The version number and copyright notice are displayed.

File menu

New

Choose New to open a new, blank graph window and data table. All prior data, configuration, and calibration information will be lost.

Open

Choose Open to open a previously stored experiment file. In addition to standard open-file dialog features, there is a check-box which when filled will cause files to be opened as read-only. A read-only file can be used for data collection, but if the user clicks or chooses Save an error message will be displayed, protecting the original file. A read-only file can be saved under a new file name using Save As…. The default is to open files as read-only.

Close

Close closes the current experiment without quitting Logger *Pro*.

Save

Save will record the current experiment to disk. If the experiment has not been saved before, Save is equivalent to Save As. If the experiment has been previously saved, the experiment file is updated.

Save As…

This will save the current experiment setup with any data in the data table. Opening this file later will restore Logger *Pro* to its current setup.

Import Data

Use this feature to import data saved with the Export Data option also found in the File menu. These data exist in a tab-delimited text format, and are imported into the Latest data run. Each file has a specific structure that includes a time stamp, data column names, short names, units, and data. If you make changes to the exported file, be sure to preserve the original structure. After choosing this option, select the appropriate file. If you plan to collect data after importing, you may need to configure the sensors before importing data. (See How To Configure Sensor Functions in this manual.)

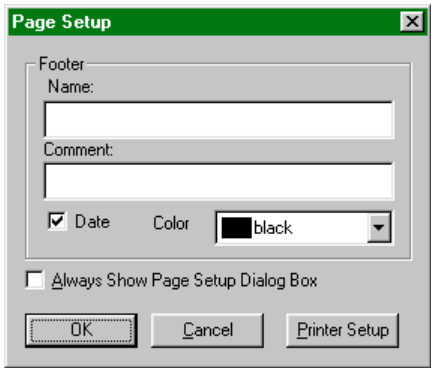
Export Data

This option exports data to a tab-delimited text file. Only raw data including time and manually-entered data from the Latest data run are exported to the file. Calculated columns or curve fit columns are not saved. A time stamp, column names, short names, and units are saved to the beginning of the file. After choosing this option, enter the name of

the file you wish to create. **Note**: Do not confuse this option with the Save or Save As options which save all the details of the current experiment. Use the Export Data option only if you want to create a file that can be read by other applications such as spreadsheets or word processors. You can instead use copy and paste features to transfer data to other applications.

Page Setup

Page Setup calls a dialog box in which you can set text that will be printed with any graph or data table. This helps to identify printouts coming from a shared printer. If the Date field is checked, the date and time of printing are included on the page. If the Always Show Page Setup field is checked, this dialog box will be displayed whenever the print command is issued. In that case, clicking OK will then display the Print dialog box where the number of copies is set.



Printer Setup

Print Setup will display the current printer's setup dialog. Options such as print quality and paper source can be chosen here.

Print

Choose Print to print either a graph or data table window, whichever window type is active. If the active window is a graph window with more than one pane, you will given a choice of printing one pane or all panes. The available options will depend on the type of printer available.

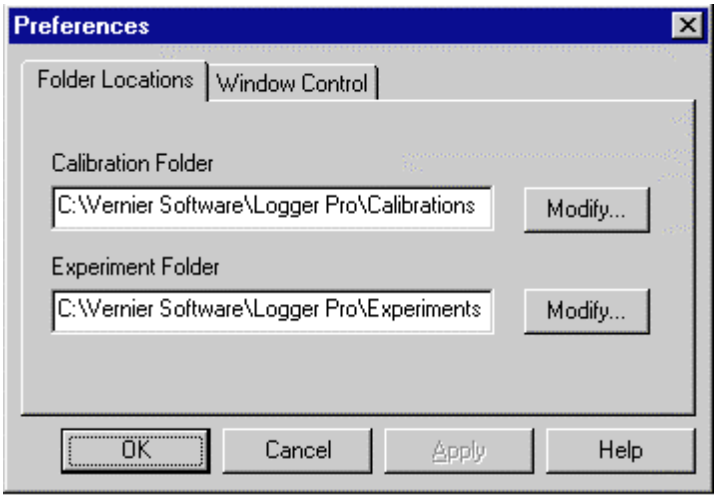
Print Preview

Print Preview will show a reduced-size image of the page as it will be printed. This is useful to ensure that a given print request won't take too many pages.

Preferences

There are two classes of Logger *Pro* settings under user control: default file locations, and a display option.

The default locations of calibration information and experiment files can be set using the Folder Locations tab.

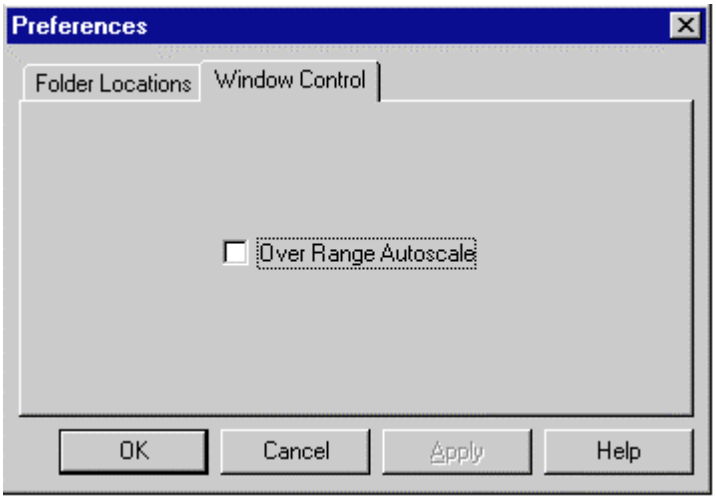


Logger *Pro* will only detect calibration files stored in the default calibration folder. New calibration files are saved to this folder as well,

and will subsequently be available in the list of calibrations in the Sensor Setup dialog box.

In contrast experiment files may be stored anywhere, but Logger *Pro* will first look in the default location set here.

To set either folder location click the appropriate Modify button and navigate to the desired folder, or just type in the full path to the desired folder.

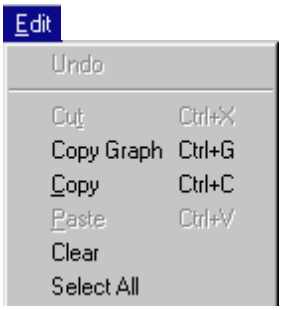


The Window Controls tab allows you to set the Over Range Autoscale functions. During data acquisition the data may exceed the existing range settings of the graph. If this box is checked, Logger *Pro* will automatically autoscale the graph during data acquisition to include all data acquired so far.

Quit (Macintosh) or Exit (PC)

Choosing Quit or Exit causes Logger *Pro* to prompt you to save any unsaved data, then exits the program.

Edit menu



Undo

The Undo command will reverse the effect of the most recent operation (if possible). For example, after data collection, the Undo command becomes Undo Collect. This is valuable if the previous run is needed but had not been stored.

Cut

Cut removes the selected data and places it on the clipboard. Not all data may be removed. Measurements made by Logger *Pro* directly (the raw data) are locked and cannot be deleted. New columns that you create are unlocked and can be edited or cleared.

The locking of raw data columns is an intentional feature of Logger *Pro*. Since the raw data are simply a record of what is measured by the sensor, it is inappropriate to change them, much as a scientist never erases data from a notebook.

Copy Graph

When a graph window is the active window, Copy Graph will place a copy of the graph on the clipboard. You can then paste the graph into a word processor or other application.

Copy

Copy places a copy of the selected data on the clipboard.

Paste

Paste places a copy of the clipboard contents at the cursor location. Pasting is possible in the text window and into Manual Entry data columns.

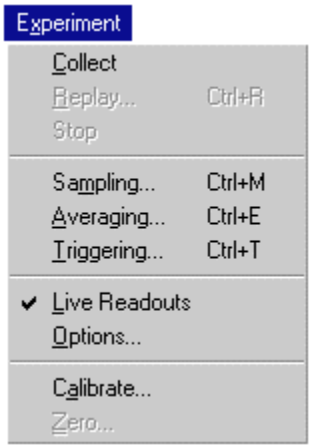
Clear

Clear removes the selected data without putting them on the clipboard. Locked data such as original data may not be removed. Only manually entered data may be cleared.

Select All

Select All is used to select the entire data table for subsequent copying.

Experiment menu

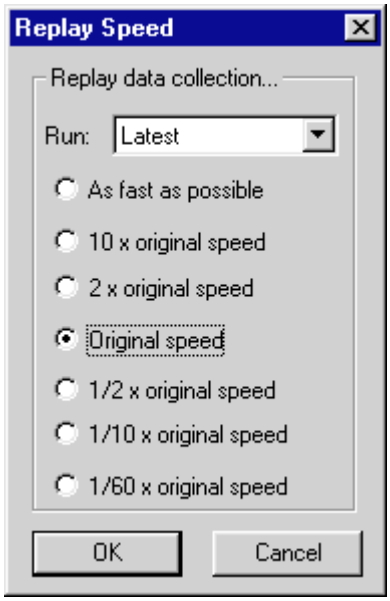


Collect

Collect begins a data collection run. Clicking the Collect button in the toolbar has the same effect.

Replay

After data are collected, choose this item to get an instant replay of the data collection. Select the run you wish to replay from the drop-down menu. You can set the replay rate to faster than real time, slower, or to the original rate.



Stop

Stop causes data collection or replay to cease.

Sampling

Sampling opens the Sampling tab of the Setup Data Collection dialog box. For additional information see the discussion under Setup menu.

Averaging

Averaging opens the Averaging tab of the Setup Data Collection dialog box. For additional information see the discussion under Setup menu.

Triggering

Averaging opens the Triggering tab of the Setup Data Collection dialog box. For additional information see the discussion under Setup menu.

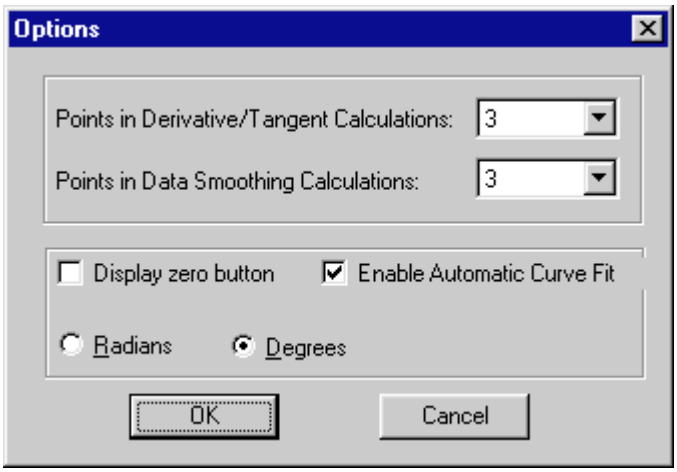
Live Readouts

This is a toggled mode. Choose Live Readouts to turn the mode on; choose it again to turn off. When the Live Readouts mode is on, the current sensor readings will be displayed in any meter window. When Live Readouts is disabled, the meter window reports the sensor value on the graph nearest the cursor position. The current sensor readings are always displayed in the status bar.

Options

Logger *Pro* uses a range of points to calculate derivatives, tangent line slopes, and smoothed data. You can set the number of points used for these functions. The first setting affects the derivative( ) function used in column definitions as well as the drawing of tangent lines. The second setting affects only the smooth( ) function used in column definitions.

In either case, a smaller number of points will make the functions more responsive to small changes in the data, but larger numbers will reduce noise.



If the Display zero button item is checked, a Zero button will be placed on the toolbar. The zero button will tare (zero) the reading of applicable analog sensors such as the Force Probe.

The Enable Automatic Curve Fit option is checked by default. Unchecking it will disable the Curve Fit function from the Analyze menu and the Toolbar. Users may wish to disable automatic curve fits to force students to perform manual fits instead.

The choice of angular units used in trigonometric calculations in Logger *Pro* is selected by clicking either Radians or Degrees.

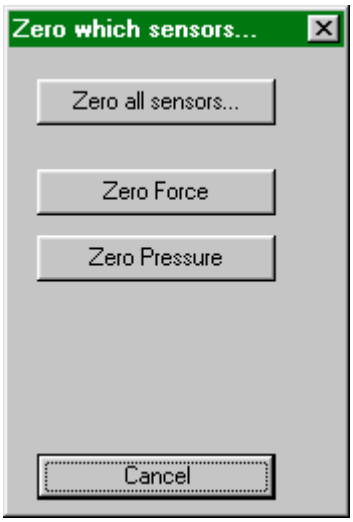
All settings in the Options dialog are stored with an experiment file.

Calibrate

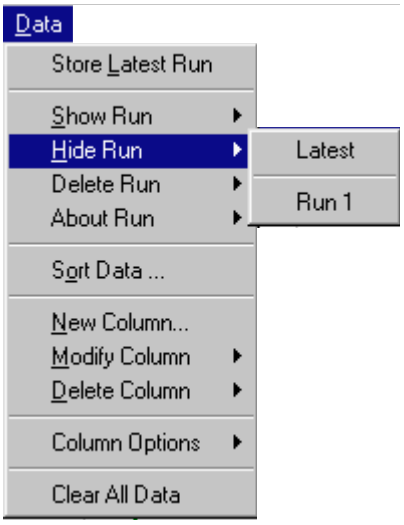
Calibrate is a shortcut to the Calibrate tab of the Sensor Properties dialog. The sensor setup discussion below give step-by-step instructions for performing a calibration.

Zero

Zero resets a sensor to zero without otherwise changing its calibration. Zero is primarily used with force sensors, but can be used with any analog sensor, as well as the Motion Detector and the Rotary Motion Sensor. If two or more sensors are active, the following dialog box is presented, allowing you to choose which sensor(s) are to be zeroed.



Data menu



Store Latest Run

To preserve a run in memory choose Store Latest Run. If you do not store it, the next time the Collect button is clicked the latest run will be deleted automatically. Stored runs are numbered sequentially as Run 1, Run 2, and so forth. You can store as many runs as your computer's memory allows.

Show Run →

Show Run is a hierarchical menu which allows you to select which runs will be shown on the graphs and data tables. The number of choices depends on how many runs you have stored.

Hide Run →

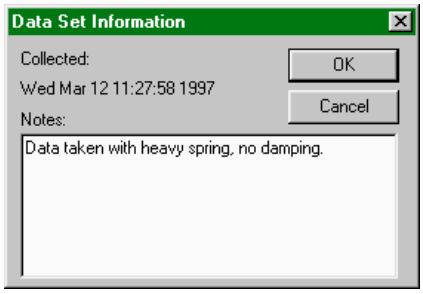
Hide Run is also a hierarchical menu. It allows you to keep a run from being plotted or shown in the data table. You can choose between the latest run and any stored runs.

Delete Run →

Delete Run allows you to remove any stored run from memory, as well as the latest run.

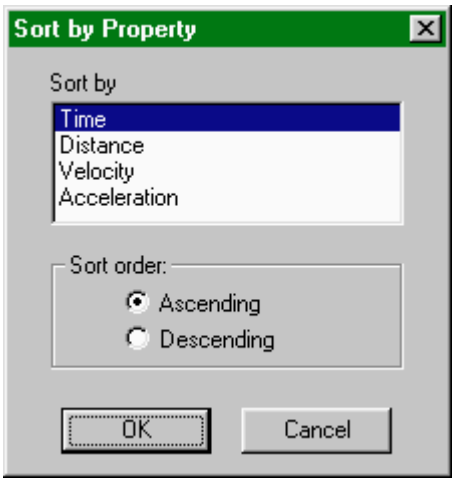
About Run →

Choosing a run from the hierarchical menu of About Run shows the time the data were collected. A text area allows you to enter notes about a run. This information is only available by again choosing About Run.



Sort Data

Sort Data will arrange rows in the data table according to values of the selected column. This function is useful if data were gathered in another order, and now you want to integrate or plot the data with connecting lines.

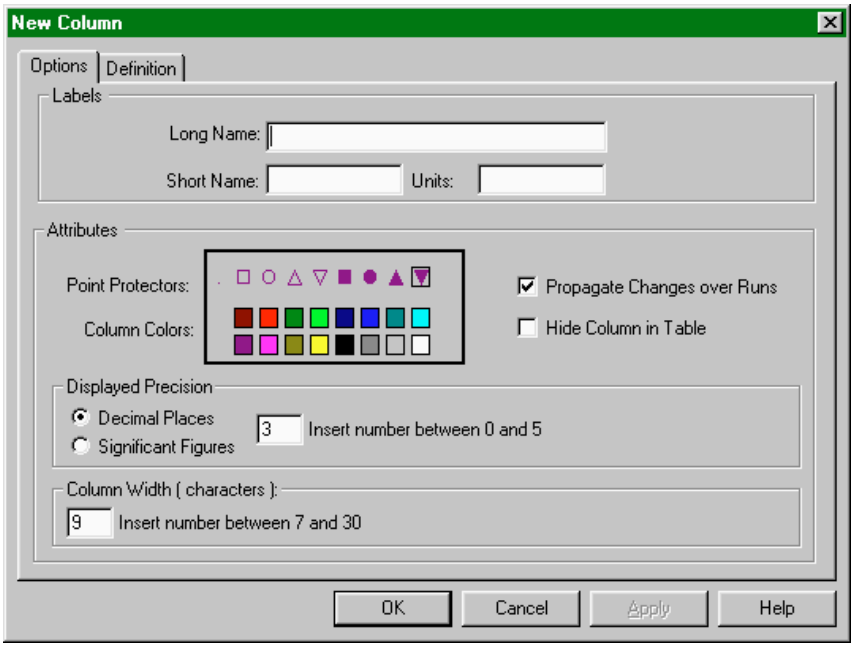


On selecting Sort, you will see a dialog in which you can choose the column which will determine the sort order, and whether the sort is ascending or descending.

Once you have sorted a data column, the sort will be performed on all subsequent runs as the data are collected.

New Column

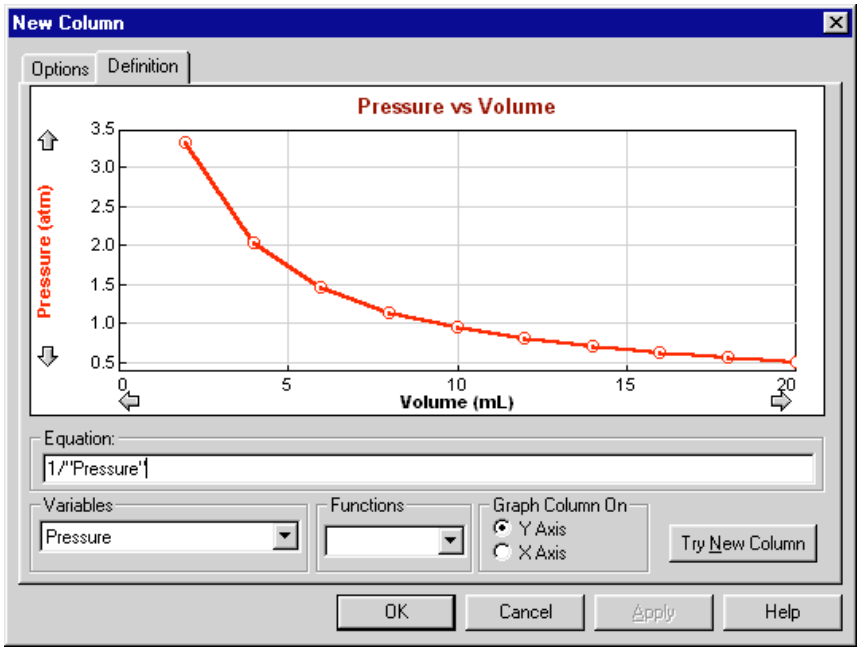
This command allows you to define a new column of data that will appear in the data table and optionally on the graph. The new column may be either a column calculated from other columns using a formula, or it may be manually entered. For both types of new columns a tabbed dialog box appears. The new column must be named and may be given units.



New Column → Formula

After setting the new column name and units, formula-based new columns require a defining formula. The definition tab allows you to

define new columns based on other columns using an equation. To create new column based on an equation, enter the desired relationship in the equation field. The contents of existing columns can be chosen from the Variables menu, and common mathematical functions can be chosen from the Function list. For more information see the tutorial on creating new columns.



The functions include several appropriate to columns of data:

integral

The integral function gives the running sum of the product of point values and the increment of the independent variable, which is usually time. That is, it delivers the numerical integral of the data column.

derivative

The derivative function gives the slope of the indicated function with respect to the column plotted on the horizontal axis. Only the dependent variable (y axis) is specified in the function. The independent variable (x axis) is determined by the graph. For example, if the graph were pH *vs.* Volume, derivative("pH") will be ΔpH/ΔVol. The number of points used in determining the slope is controlled in the Logger *Pro* preferences found under the File menu.

smooth

The smooth function reduces noise in the indicated column. The number of points used for a moving average is controlled in the Logger *Pro* preferences found under the File menu. There is no loss of data points from smoothing.

Graph Column On

The calculated column can be graphed on either axis. The default choice is the y axis. Click the x-axis label to plot the new column on the horizontal axis.

Try New Column

Clicking the Try New Column button will graph the new column in the sample graph. You can make changes to the definition, and check out the changes by clicking this button again. Click OK to keep the new column and return to the main Logger *Pro* screen. Cancel will close the dialog box and discard any entries.

New Column → Manual

Manual columns only require a name. The new column will be created in the data table. Select a cell by clicking it. Type in your values, ending each entry with the return key. You can also paste a column of data after clicking the first cell. Manual columns are limited to the number of data points already collected using a sensor.

Modify Column

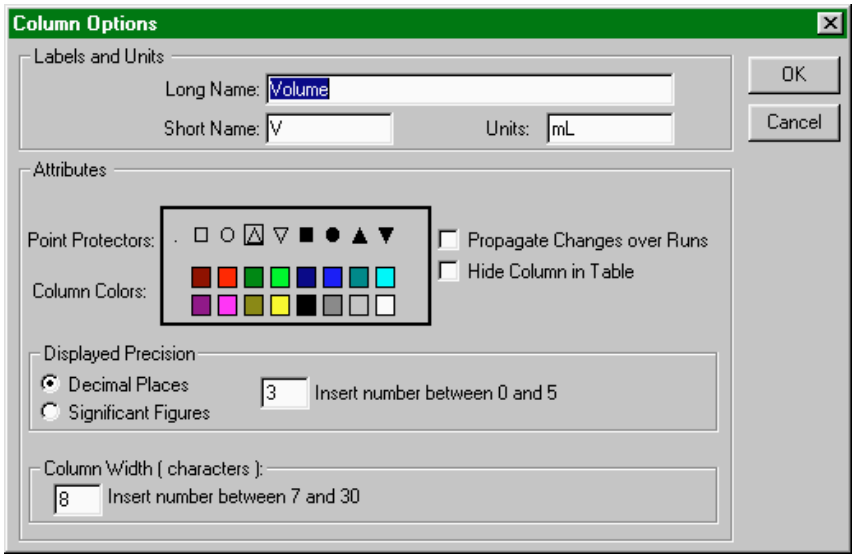
Modify Column allows you to change the definition of a calculated column. The same dialog box as for New Column above is displayed.

Delete Column

Use Delete Column to remove unneeded columns.

Column Options

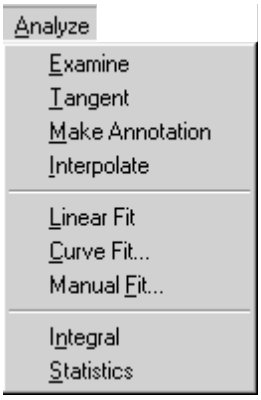
Column Options opens a dialog in which you can change the name of the column, change the point style used, units, and displayed precision of data. Use this option to modify existing columns.



Clear All Data

Clear All Data removes all data from the data table. You will be prompted to save any unsaved data.

Analyze menu



Examine

Examine is a toggled mode. When active, the mouse pointer becomes a vertical line and the value of the data at the indicated time is displayed in the graph legend.

Tangent

Tangent enables the drawing of a short tangent line at the cursor location to each data column plotted. The numerical value is displayed in a floating box. The number of points used to calculate the slope can be set in under Preferences in the File menu.

Make Annotation

Make Annotation allows you to create a floating box with any text you choose. This is useful for placing comments on graphs. To edit an annotation, double click on the floating box. To remove an annotation, click the close box on the upper right corner of the floating box.

Interpolate

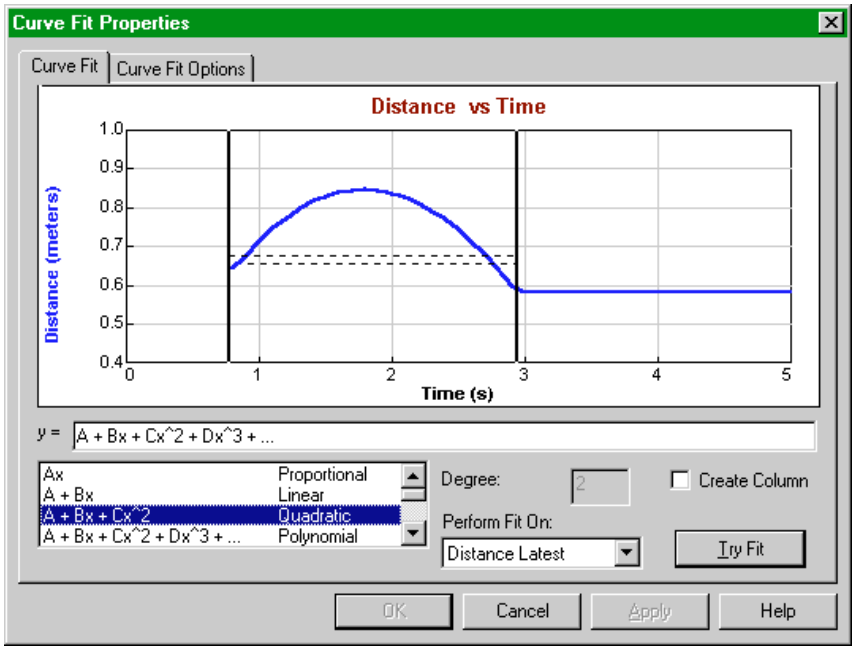
The interpolate function can only be used after a function has been fit to experimental data. After choosing interpolate, the value of the fitted function is displayed as a function of cursor position.

Linear Fit

Linear fit performs a linear least-squares fit on the selected data. If there is no selection made the entire data run is used.

Curve Fit

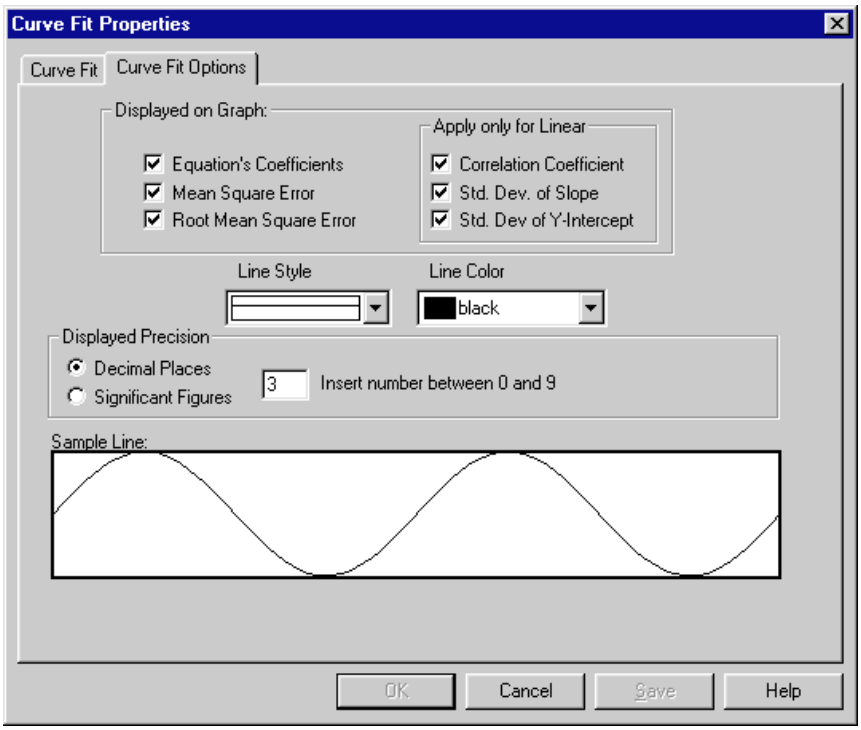
The Curve Fit item gives you a choice of advanced curve fitting options. These curve fits are automatic in the sense that the fit parameters are determined by Logger *Pro* using least-squares methods. The dialog box below is opened.



The graph portion of this window gives you a preview of the fit and allows the selection region to be modified. To perform a curve fit, choose first the type of fit from the scrolling list at lower left. For the case of the polynomial fit, enter the degree of the polynomial in the Degree field. Next, choose the column to be approximated by the fitted equation. Click on Try Fit to see the result. Modify your choices as desired. You can modify your data selection by repeating a drag across a portion of the data and clicking on Try Fit again. Once you like the fit, Click on OK to place the fit on the main graph window, or Cancel to discard the fit altogether.

Clicking Create Column will place a new column in the data table containing the value of the fitted equation at each time.

The Curve Fit Options tab holds a new dialog box.



The Curve Fit Options tab allows you to determine which fit statistics are displayed on the graph. The Equation's Coefficients are the fitted parameters. The Mean Square Error and its square root, the Root Mean Square Error, measure how far away on average the fitted function is from the data. The Root Mean Square Error is in the units of the data on the y-axis.

You can also specify the style and color of the line representing the fit. The Sample Line region provides a preview of the line appearance.

The Displayed Precision field allows you to set the number of displayed digits in the curve fit floating boxes. Select one of Decimal Places (a fixed number of places past the decimal point) or Significant Figures (the number of digits displayed, plus any need to show magnitude). Enter the desired numerical setting for either mode.

For the linear fit only, the fit and its statistics are determined as follows. We have N ordered pairs of x_i and y_i. The best fitting line $y = ax + b$ is then given by

$$a = \frac{1}{\Delta}\left(\sum x_i^2 \sum y_i - \sum x_i \sum x_i y_i\right)$$

$$b = \frac{1}{\Delta}\left(N\sum x_i y_i - \sum x_i \sum y_i\right)$$

$$\text{where } \Delta = N\sum x_i^2 - \left(\sum x_i\right)^2$$

Measures of the goodness of fit are many. Most common are the scatter standard deviation, σ_s, the linear correlation coefficient r, and the uncertainties of the parameters a and b, σ_a and σ_b. The scatter standard deviation measures how far away, on average, the data points y_i fall

from the fitted line, measured along a vertical line.[5] σ_s is also called the root mean square error, and is defined as

$$\sigma_s = \sqrt{\frac{1}{N-2}\sum\left(y_i - a - bx_i\right)^2} \ .$$

We use N - 2 weighting since two parameters have been determined in the curve fit.

The remaining quantities are defined as

$$\sigma_a = \sqrt{\frac{\sigma_s^{\ 2}}{\Delta}\sum x_i^2}$$

$$\sigma_b = \sqrt{N\frac{\sigma_s^{\ 2}}{\Delta}}$$

$$r = \frac{N\sum x_i y_i - \sum x_i \sum y_i}{\left[N\sum x_i^2 - \left(\sum x_i\right)^2\right]^{1/2}\left[N\sum y_i^2 - \left(\sum y_i\right)^2\right]^{1/2}}$$

The first two quantities are interpreted as the variance of the fitted parameters, and so can be used as 67% confidence level uncertainties of the slope and intercept.

The correlation coefficient, *r,* is commonly calculated by scientific calculators, but is a difficult quantity to interpret. The correlation coefficient is intended to measure the degree of correlation between the *x* and *y* values. It is not directly a measure of goodness of fit. For no correlation at all (random values), *r* is near zero. For perfect correlation *r* is ±1. From *r* one can determine a probability that the *x* and *y* values are correlated. In the natural sciences, however, there is usually the assumption that the two *are* correlated, and so the *r* value is not very useful. Far more useful to a student or scientist is the uncertainty of the slope and intercept. These uncertainties answer the question “How well did the data determine a slope (or intercept)?”.

No provision has been given to weighted fits, since in computer-acquired data all data points are generally equally reliable.

More information on curve fitting and the interpretation of the fitted parameters can be found in *Data Reduction and Error Analysis for the Physical Science*, 2nd edition, Philip R. Bevington and D. Keith Robinson, McGraw-Hill, Inc., 1992.

The curve fit function can be disabled in the Options, found in the Experiments menu.

Manual Fit

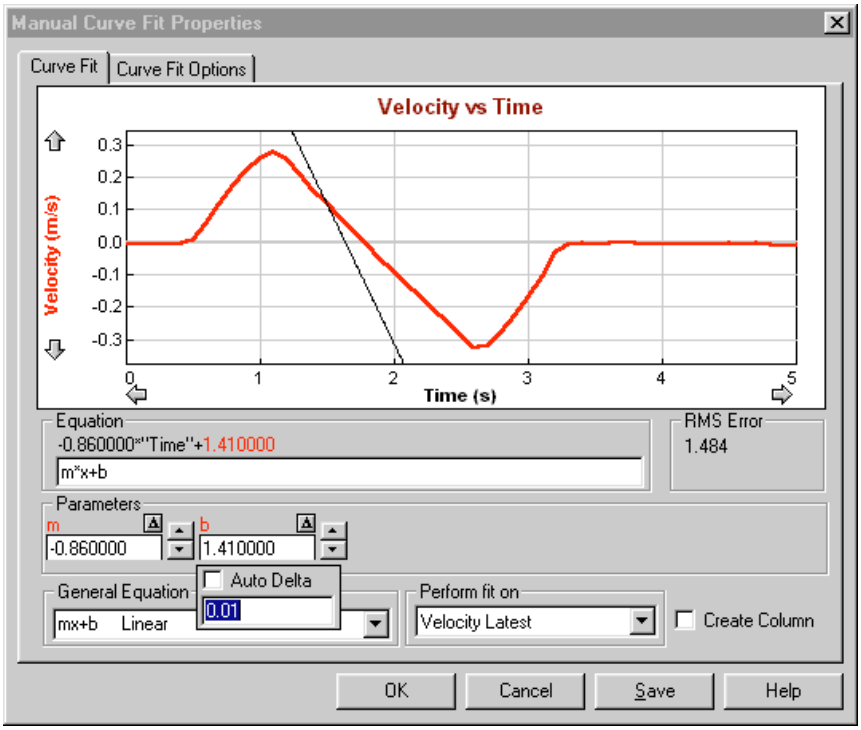
Logger *Pro* will superimpose a function (sometimes called a model) over your data using the Manual Fit option. In contrast to the curve fit discussed above, where the parameters in the fit equations are determined automatically using a least-squares technique, the Manual Fit allows you to adjust the parameters by hand.

A manual fit is often appropriate for instructional purposes. By adjusting parameters manually, students will learn how each affects the fit. A manual fit will also allow you to adjust a curve to fit a data series in the way you want, possibly ignoring certain stray points within the series.

To perform a manual fit, click once on a graph to make it active. Optionally, select a region of the graph using the mouse. This selection

[5]The least squares fitting method *assumes* that the uncertainties in the *x* values are negligible compared to the uncertainties of *y*.

region is used only for calculating the mean square error of the fitted function with respect to the data. If you do not plan on using the mean square error value, then it is not necessary to select a region. Then, select Manual Fit from the Analyze menu. A new dialog box will open.



First, you must select or enter an equation. The faster method is to select an equation from the General Equation menu. In the screen shown above, the linear relation y = mx + b has been selected. You can also enter your own relationship in the Equation field. The equation must contain between one and five adjustable parameters (single upper- or lower-case letters) and the horizontal axis variable is entered as **x**.

The values of each parameter may be adjusted in the Parameters fields. You can either type in a new value directly, or you may use the up and down arrows to increase or decrease the values using the mouse. Click, or click and hold, on the desired arrow.

The Δ button near each parameter allows you to set the adjustment increment applied when the arrows are used. The Δ button for the b parameter has just been clicked in the screen above. If the Auto Delta box is checked (default is unchecked) then the increment will be made smaller when the parameter reaches a magnitude similar to the increment.

Using the manual fit can be very helpful in understanding fitted functions, but it can also be frustrating. A random or poorly-chosen set of parameter values may result in a function which does not cross the graphed region at all. Blind adjustment of the parameters will not often move the function into view. Once a part of the function is in view, it is usually easy to adjust the parameters to get a good fit.

If your graph starts at x = 0, one way to get the function into view at the start is to adjust the y-intercept value to match that of your data. Then you will see at least a portion of the function, allowing you to adjust other parameters as needed.

Clicking Create Column will place a new column in the data table containing the value of the fitted equation at each x-axis value.

The Perform Fit On menu allows you to select the column used for calculating the Mean Square Error value. The Mean Square Error measures how far away the function is, on average, from the data. Automatic curve fits seek to minimize this value.

Integral

Integral performs a numerical integration on the selected data. First drag across the desired region of your data to select. Then choose Integral (or click on the Integral button on the toolbar). You will have the opportunity to specify which data set you want to integrate. The numerical result is shown on the graph, and the corresponding area shaded.

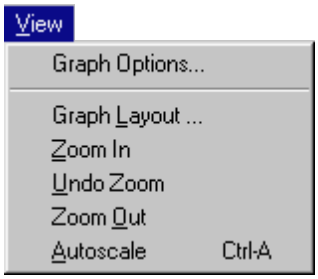
Statistics

The Statistics item displays a dialog showing statistical measures of the selected data: maximum, minimum, mean, standard deviation, and the number of points used. You may optionally select a region of the data first. The entire data set is used when no selection is made. After you select Statistics (or click on the Statistics button on the toolbar) you will have the opportunity to specify for which data set you want statistics calculated. The statistics are presented in a floating box on the graph screen.

The standard deviation is found using *N-1* weighting, or

$$\sigma = \sqrt{\frac{1}{N-1}\sum\left(x_i - \bar{x}\right)^2} \ .$$

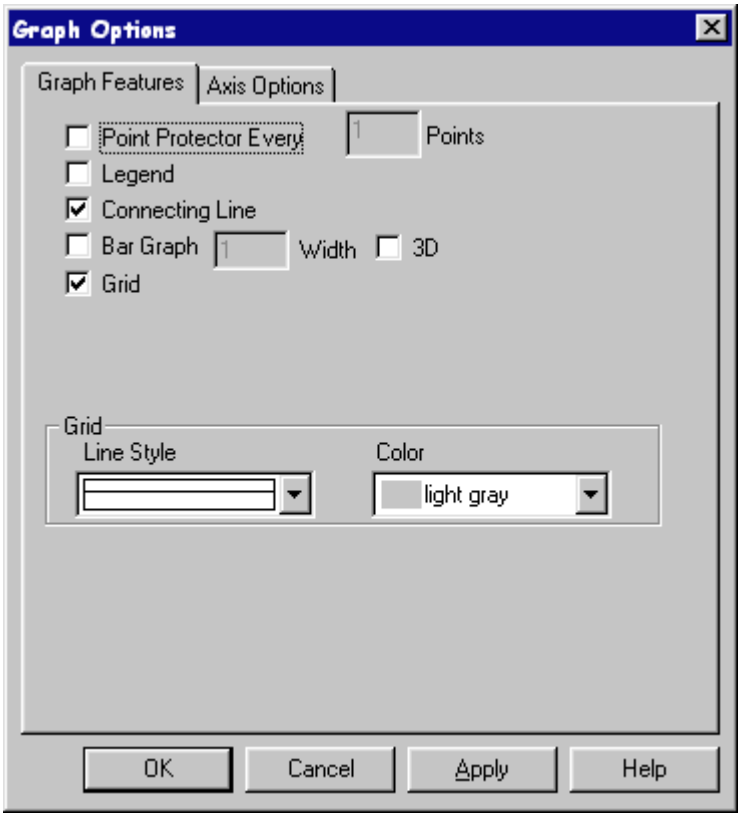
View menu



The first item in the View menu changes depending on the active window. For example, to see Data Table Options, click once on a data table before pulling down the View menu. Options settings for Text, FFT, and Meter windows are also available.

Graph Options

Choosing this item is equivalent to double clicking the graph. The Graph Features tab of the dialog box is shown first:



Point Protector Every … Points

If this item is selected, a marker will encircle one of every *N* points. Marker color and shape can be chosen by Choosing Column Options from the Data menu.

Legend

Selecting Legend causes a legend to appear on the graph. The Legend identifies the plotted columns by color and line style. A Legend appears automatically when in Examine mode.

Connecting Line

Enabling Connecting Line draws a straight line from one data point to the next.

Bar Graph

If this option is selected Logger *Pro* will draw vertical bars from the horizontal axis to each data point. The bar width in pixels can be set in the width field.

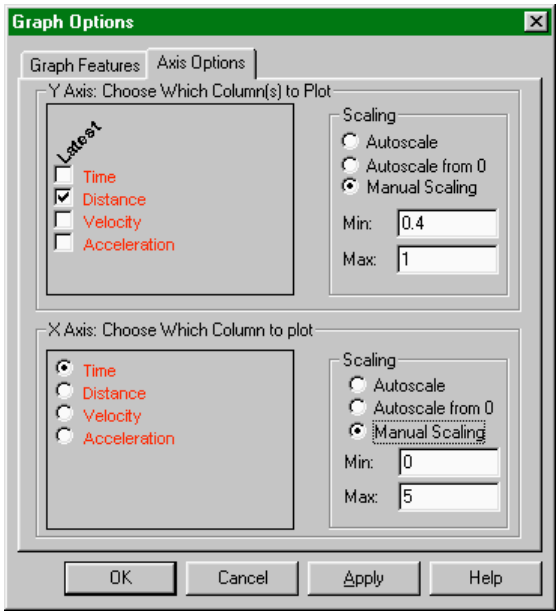
3D

If this option is selected, Logger *Pro* will draw the vertical bars of a bar graph with shadows, giving an illusion of depth.

Grid

A gridline for every tick mark can be displayed if desired. The color and weight of the lines are controlled using the two pop-up menus at the bottom of the dialog box.

The Graph Options dialog also has an Axis Options tab:

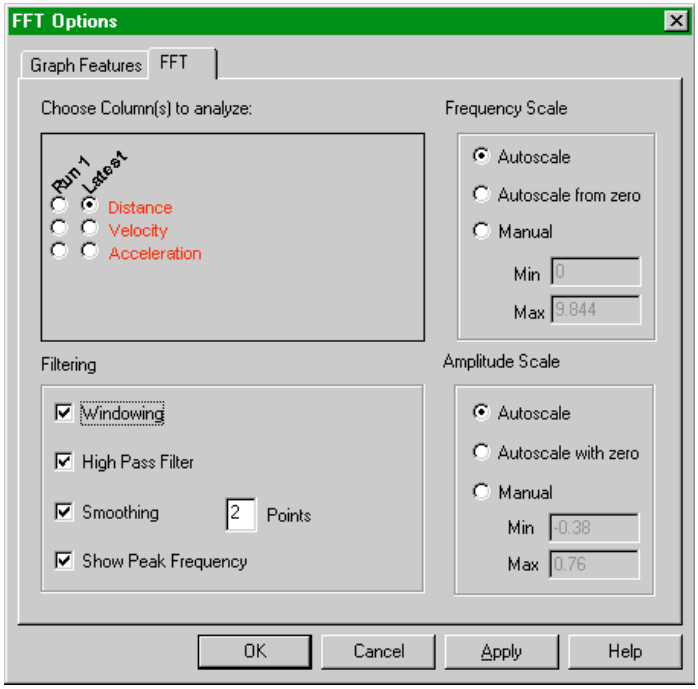


Here you can control what is plotted on the two axes as well as the scaling used. The settings here are duplicated in the axis scale and selection dialogs obtained by double-clicking an axis or axis label. The columns shown will depend on your specific configuration of Logger *Pro*. Scaling choices will also be used in subsequently collected data.

FFT Options

FFT Options allows you to control the way the Fast Fourier transform is calculated and the way the graph is drawn. The Graph Features tab allows you to set the same features found on the Graph Options dialog, describe just above.

The FFT tab determines how the FFT is calculated:



Choose Column(s) to Analyze:

The columns available will depend on the columns currently in the data table.

Filtering

A raw FFT often will have undesirable artifacts which can be reduced by appropriate filtering.

Windowing reduces the weighting given to the first and last 10% of the data sequence. This reduces high frequency artifacts due to the abrupt beginning and end of data.

Turning on High Pass Filtering will ignore any constant or linearly dependent component to the data.

Smoothing will reduce noise in the final FFT by performing a running average on the raw data before the FFT is calculated.

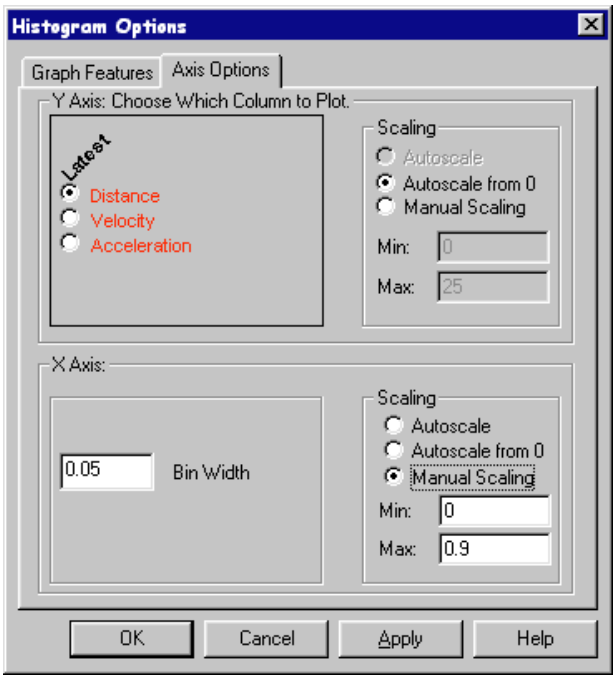
Enabling Show Peak Frequency will display the highest amplitude frequency.

Scale

Set the desired scale of the FFT frequency (horizontal) and amplitude (vertical) axes.

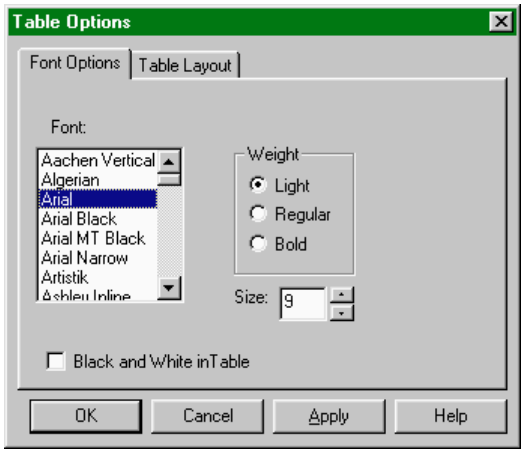
Histogram Options

The Histogram Options dialog box controls the appearance of a histogram. The Graph Features tab is a subset of the standard Graph Features tab, while the Axis Options tab allows control of the histogram bin width. The data to be displayed and the scaling of the x- and y-axes is set as before.



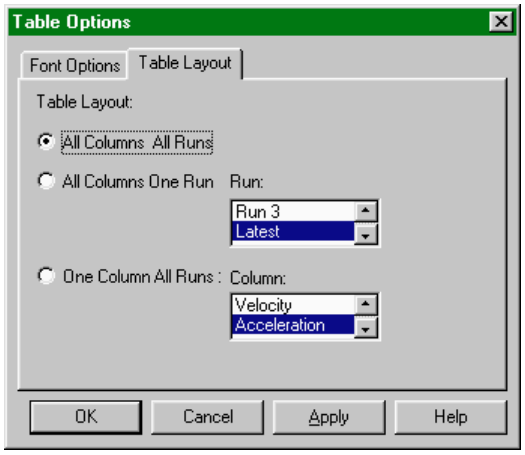
Data Table Options

Data Table Options lets you control the font, size, and presentation of data columns through two tabbed dialog boxes. The first sets the font, weight and size of the numerals:



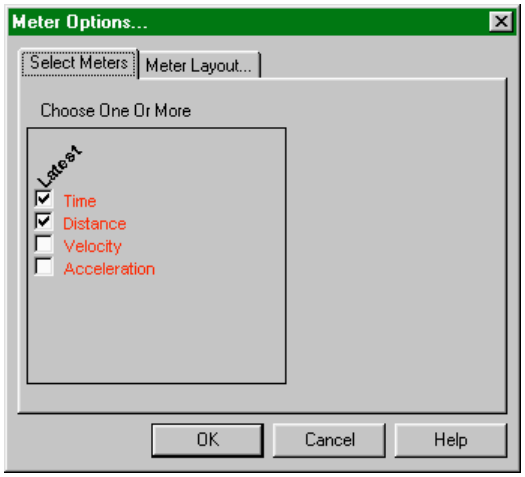
Choosing Black and White in Table will disable the use of color coding of the columns, which may make reading values somewhat easier.

The Table Layout tab controls what columns are shown in the table. You may want to hide some columns for clarity. The first option shows all data. The second allows you to show just one selected run, and the third lets you display one selected column across all runs. You can also hide individual columns in the Column Options dialog box.



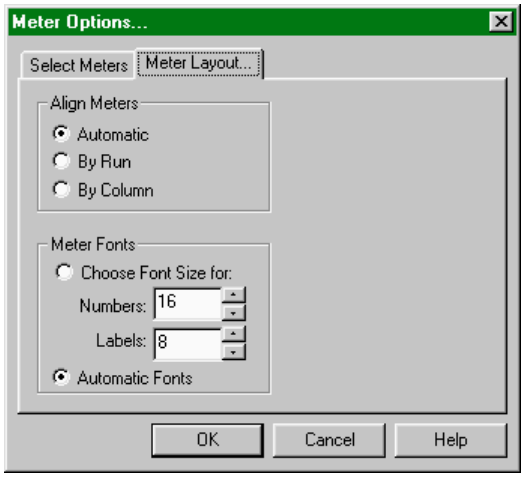
Meter Window Options

The data columns displayed in the meter window can be set by the user in this dialog box.



Meter Layout

In addition you can control the layout and font size of meter window readouts.

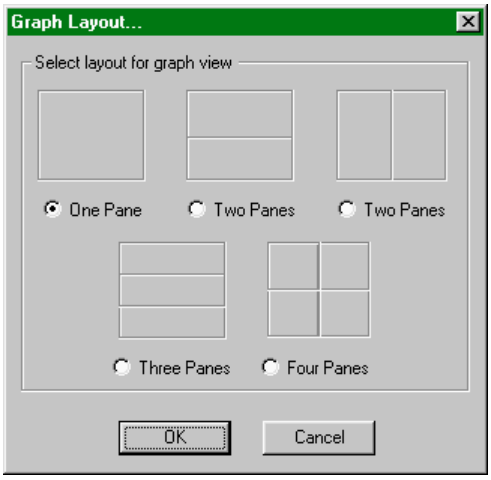


The three grid layout options determine whether the meters are laid out to fill the available space with the largest possible meters (Automatic), to arrange data from each run vertically (By Column) or horizontally (By Run).

The type size used in meters can either be set by the user or determined automatically.

Graph Layout

Graph Layout allows you to control the way multiple graph panes are shown in the graph window. Choose the desired option and click on OK.



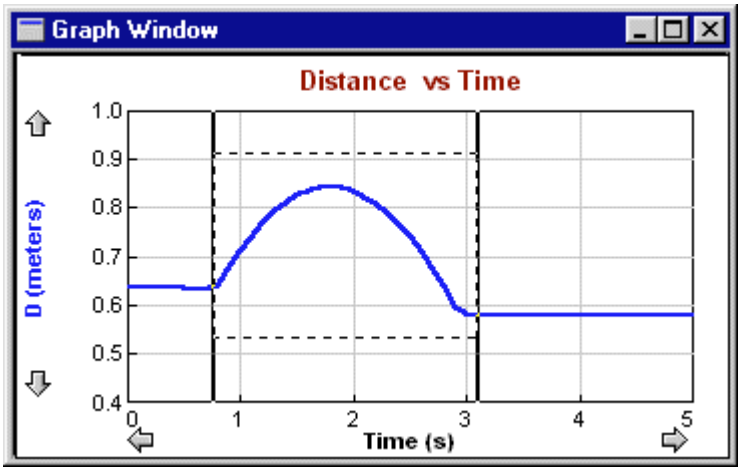
There are two ways to display multiple graphs in Logger *Pro*; one is to use two or more graph windows, and another is to use the Graph Layout command to display two or more graph panes within a single window. Graphs in separate windows are independent of one another, although both depend on the same data table. Graph panes in a single window share certain adjustments for ease of viewing. These shared parameters are:

- Changing the x-axis limits in one pane will automatically change the limits in other panes.
- Scrolling the x-axis plotting range using the scroll arrows will scroll all panes.
- Zooming into a selected region will zoom the horizontal axis of all panes in the same manner.

These connected adjustments will keep the horizontal axes synchronized to allow easy comparison of each series. If you want independent adjustment of the horizontal axes, use separate graph windows.

Zoom In

To zoom in on a portion of a graph, first draw a rectangle on the graph screen by dragging the mouse across the desired area as you see here.



Then choose Zoom In from the View menu, or click on the Zoom In button on the toolbar. The graph will rescale, expanding the selected region to fill the plotting area. If the Zoom In command is used on one of several graph panes in a single graph window, the horizontal axis will be changed in all graph panes.

Undo Zoom

Choosing Undo Zoom will reverse the last zoom action performed, whether by the above Zoom In command or the following Zoom Out command. You can undo multiple zooms with multiple Undo Zooms.

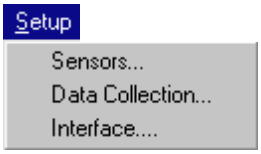
Zoom Out

The Zoom Out command will double the range of both the x- and y-axes.

Autoscale

Autoscale will change the scales so that the plotted curves fill the graph area. Both x and y axes may be changed. The y axis will not necessarily include the origin, so you may want to perform a more limited autoscale by clicking the y axis and choosing Autoscale from Zero in the ensuing dialog. You can also click on the Autoscale button on the toolbar.

Set Up menu



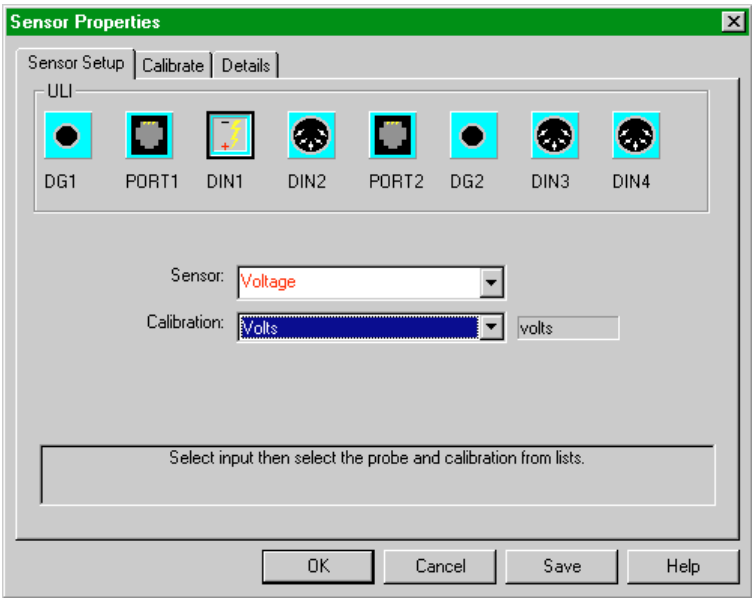
Sensors

Use the Sensors menu item to set up Logger *Pro* to work with various sensors.[6]

You will see this dialog box with three tabs. The basic sensor setup is explained below. The Calibrate and Details tabs are described in turn.

[6] The ULI inputs can be used in combination subject to these limitations:
Port 1 cannot be used simultaneously with DG1 or DIN1.
Port 2 cannot be used simultaneously with DG2 or DIN2.
DIN3 and DIN4 cannot be used simultaneously with a Motion Detector
DIN3 and DIN4 cannot be used at sampling rates over 50Hz.
For the original ULI and ULI_{II} (revision 1.00) the ULI Force Probe must be used in Port 1 and the Motion Detector must be used in Port2.

Sensor Setup tab



To configure Logger *Pro* for a particular sensor,

- Click on the input to which you attached the sensor. For example, DIN1, PORT2, and so forth.
- Choose the sensor name from the Sensor scrolling list. To turn off an input, choose None from the top of the scrolling list.
- Choose the desired calibration file from the Calibration scrolling list. Some sensors have several possible ranges or units choices. In most cases you will use the default calibration.

If you do not need to perform a new calibration, click on the OK button to complete the sensor setup.

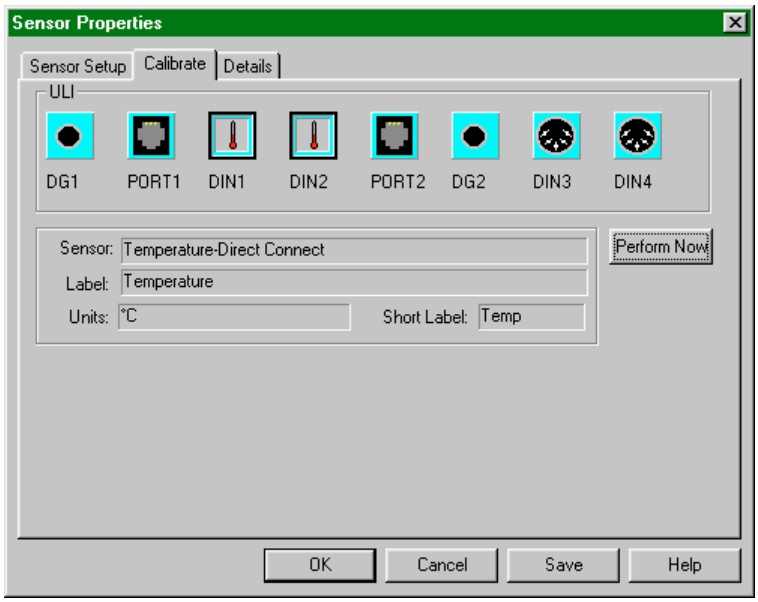
Calibrate tab

Analog sensors can be calibrated to report measurements in physical units either by manual calibration, from a stored calibration file, or by manually entering slope and intercept information (Details tab).

Choosing Calibrate opens a dialog box allowing you to select a stored calibration file or perform a new calibration. A new calibration requires two independent measurements of the quantity for comparison to the raw data readings. For example, to calibrate a temperature sensor you must have two different water baths of known temperature.

To perform a new calibration,

- choose Sensors from the Setup menu if the Sensor Setup window is not already open.
- Click on the Calibrate tab at the top of the resulting dialog box.



- Click on the input for the sensor you want to calibrate.

If you have several sensors of the same kind you can select multiple inputs to calibrate the sensors at the same time.

First calibration point

- Click on Perform Now.
- Allow the sensor and the thermometer to stabilize at the first calibration temperature. You can determine this by waiting until the displayed voltage values stop changing.
- Enter the thermometer's actual reading (in degrees) in the Value 1 field.
- Click on Keep.
- Move the sensor and thermometer to the second water bath.

Second calibration point

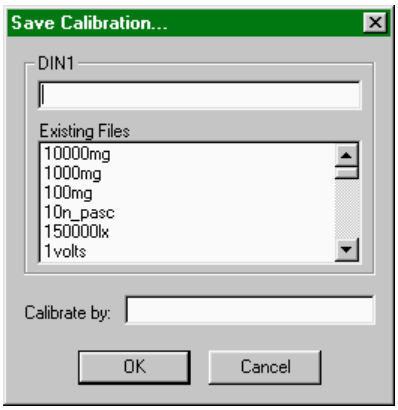
- Allow the sensor and the thermometer to stabilize at the second calibration temperature.
- Enter the thermometer's actual reading in the Value 2 field.
- Click on Keep.

Save calibration

Calibration information is automatically saved when you save an experiment file. As a result, it is not necessary to separately save a calibration result unless you want the calibration to show up in the scrolling list in the Setup Sensors tab. To make a calibration available in the scrolling list,

- click on Save to record the calibration in a separate file.

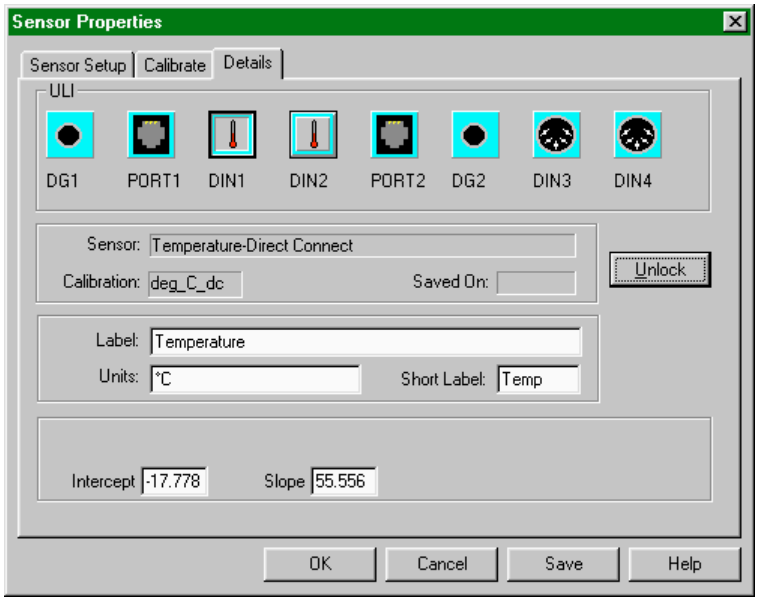
You will see this dialog box.



Enter a name for the calibration file in the first region. The scrolling list shows all the available calibration files. Optionally you may enter your initials in the Calibrated by field. Click on OK to save the file to the default calibration folder as specified in Logger *Pro* Preferences. You will be warned before replacing an existing file of your own; Vernier-supplied calibration files may not be replaced.

Details tab

Additional calibration information can be set on the Details tab of the Sensor Setup dialog:



The calibration procedure creates a correspondence between the sensor voltage output and the measured quantity (such as temperature) which can be characterized by a slope and intercept. If someone has done an earlier calibration of a sensor you can manually enter the calibration here after clicking on the Unlock button. The Labels and Units can also be changed. For example, this is where you could enter the calibration parameters for a new sensor that does not have a supplied calibration file.

Special note for Rotary Motion Sensor

The Rotary Motion Sensor is different from other sensors in that it has modes of operation that can be controlled in software. These modes are set in the Details tab of the Sensor Properties dialog box.

Counts

This field contains the number of counts a particular sensor generates for each revolution. The Vernier/PASCO sensors generate 360 counts for each revolution, while others may be different.

Zero@Start

The Rotary Motion Sensor can be set to zero at the start of data collection. Enter a **1** in this field to enable automatic zeroing. Enter a **0** (zero) for conventional zeroing.

X4 Mode

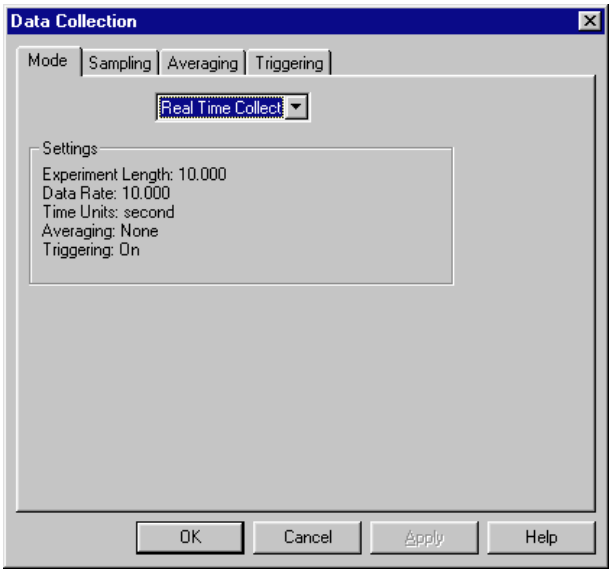
The resolution of the Rotary Motion sensor can be set to either 1º or 0.25º. When the X4 Mode field is set to 0 (zero), resolution is 1º. When set to 1, resolution is 0.25º.

Diameter

When a linear displacement calibration file is opened for a Rotary Motion Sensor, a diameter field appears. Enter the diameter of the rotary wheel so Logger *Pro* can translate the rotation of the sensor to the displacement. The units used for diameter will be the units of the reported displacement.

Data Collection

Data Collection is used to set data acquisition parameters such as data rate, triggering and mode. You can access the Data Collection dialog using the toolbar as well.



There are several data collection modes. They are selected from the drop down menu on the Mode tab.

Real Time Collect

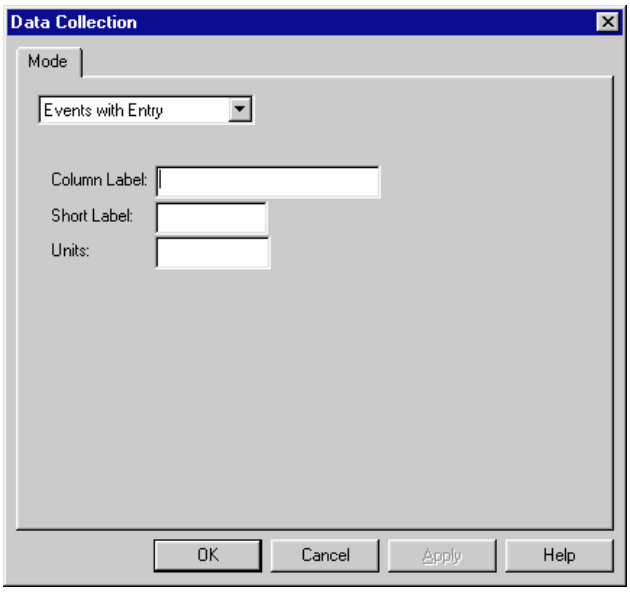
Data are collected at the rate indicated and for the experiment length set on the Sampling tab.

Repeat

Data are collected at the rate indicated and for the experiment length set on the Sampling tab. After a short pause, the run is repeated until the Stop button is clicked. Usually this mode is used to acquire run after run while an experiment is adjusted. When a useful run is acquired, press Stop. If a new run begins before you click on the Stop button you still can return to the previous run. Click stop, then choose Undo Collect from the Edit menu.

Events with Entry

A new column is defined to replace the time column. Enter a name for the column (Column Label), short name, and the column units. Data are recorded only when the Keep button is clicked. Subsequently a numerical entry field appears in the toolbar for manual entry of data. End entries with the Enter or Return key.



Selected Events

Data are recorded only when the Keep button is clicked. No manual entry column is created, and time is the independent variable.

Photogate Timing

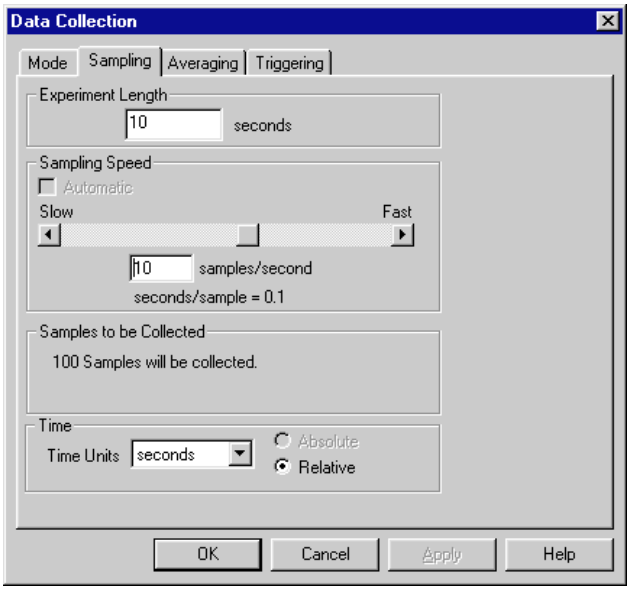
Data are collected from a photogate or Smart Pulley. The photogate mode supports seven methods of collecting data. The various modes are made available on the Sampling tab of this dialog box.

Radiation Counting

Data are collected from a Radiation Monitor or a Student Radiation Monitor. The Sampling tab allows the experiment length, mode and the length of the counting time interval to be set. The Real Time Collect mode is used for lifetime measurements, while the Events with Entry mode is used for measuring count rates on user command, similar to the Events with Entry mode for other sensors described above.

Sampling

The contents of this tab are determined by the data collection mode. When using any mode except the Events with Entry, Photogate or Radiation Counting modes, the following Sampling dialog box will appear:



Experiment length

Enter the length of time data over which data are to be collected. A maximum of 30,000 points can be collected for each input channel.

Sampling Speed

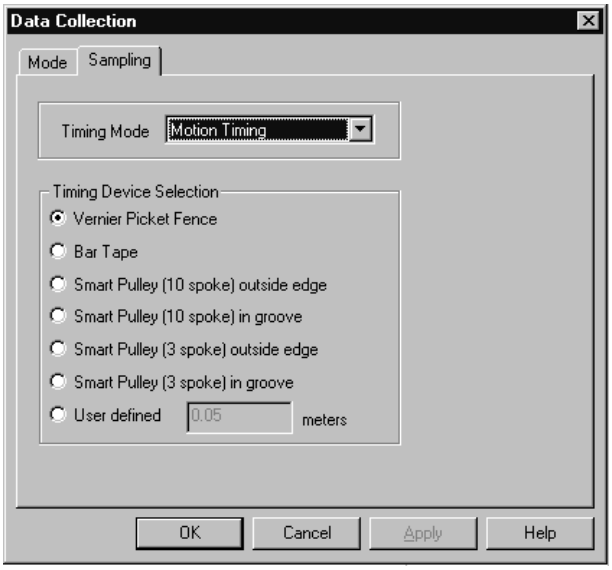
Enter the number of measurements per time unit desired. You can also adjust the sampling speed using the slider.

Time

Choose a time unit (milliseconds, seconds, minutes, hours).

Photogate Sampling

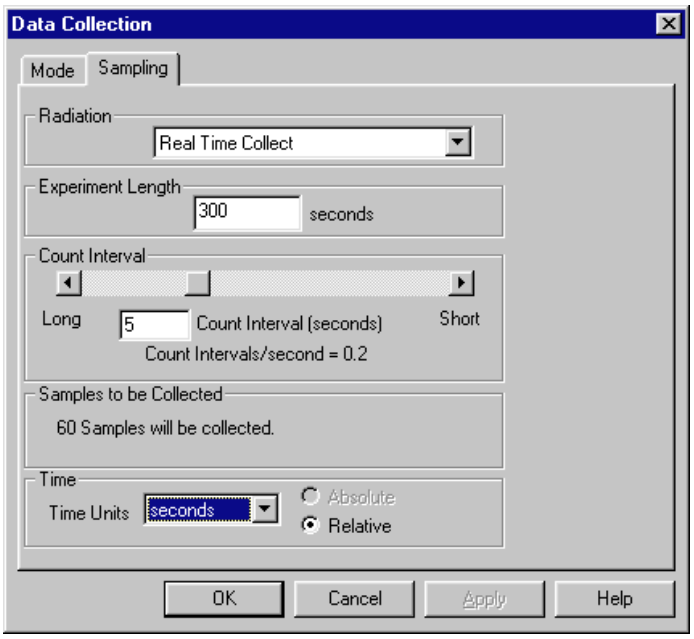
When using the Photogate mode, the following Sampling dialog box will appear:



The contents of this dialog box will depend upon the selected Timing Mode. Pull down the Timing Mode list and choose an appropriate mode. The Timing Device Selection portion of this dialog box is a function of the timing mode. If the timing mode is Motion Timing, select the type of device. If you are using a custom device, click the User defined button and enter the distance in meters between the leading edges of the device. In other timing modes you will only need to enter the length of the object that passes through the gate or gates.

Radiation Counting Sampling

When using the Radiation Counting mode, a different Sampling dialog box will appear:



Radiation

Choose between Real Time Collect and Events with Entry. The Real Time Collect mode is used for lifetime measurements, while the Events with Entry mode is used for measuring count rates on user command, similar to the Events with Entry mode for other sensors described above.

Experiment length

Enter the length of time over which data are to be collected.

Count Interval

Logger *Pro* will count the number of pulses detected during each count interval. For example, the settings shown above will have Logger *Pro* report the number of pulses during each of sixty 5.0-s long intervals, for a total collection time of 300 s.

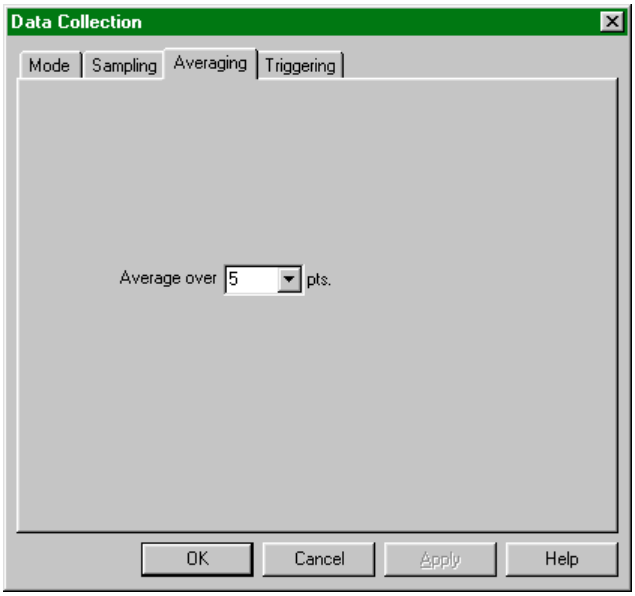
Time

Choose a time unit.

Averaging

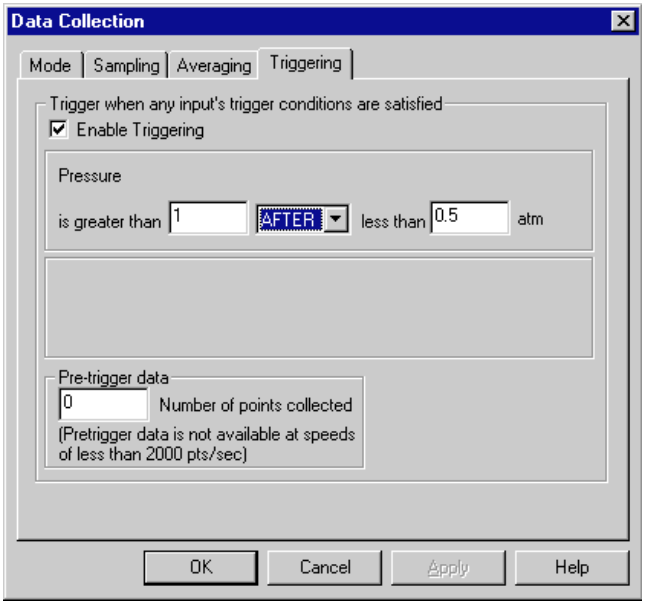
When averaging is set to a number other than one, the actual data collection rate is higher than set in the sampling speed field, and up to the indicated number of evenly spaced readings is averaged to create a single data point. The actual number of points used may be fewer than indicated due to sampling speed limitations of the interface. Averaging

is not available for digital sensors such as the Motion Detector, Photogates, or Radiation Monitor.



Triggering

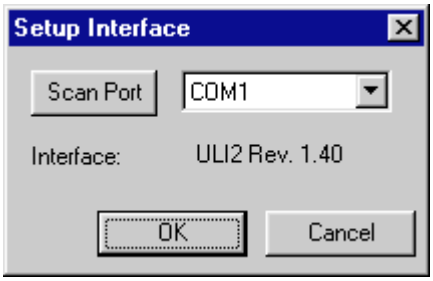
Data collection can be *triggered*; that is, data are not collected until certain conditions are met. To use triggering, click on the Enable Triggering check box, and enter the desired trigger conditions. Data collection begins when conditions are met on any one channel. When data collection rates over 2000 points/second are used, up to 128 points of data prior to the trigger condition can be acquired. Enter a number in the pre-trigger field to use this function.



Interface

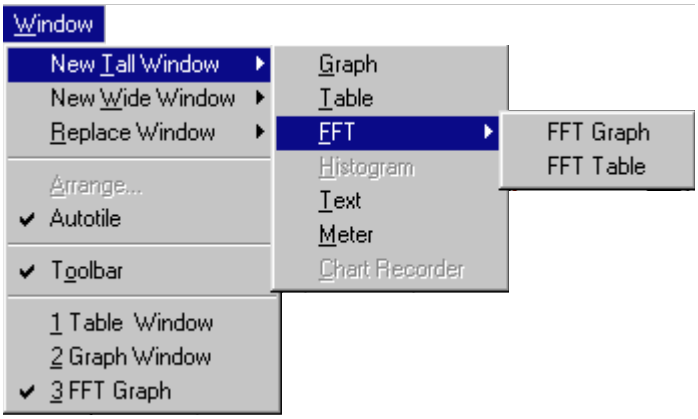
The Interface dialog box allows you to force Logger *Pro* to search for a compatible interface. The current communications channel is shown in the drop-down menu. If no channel is chosen, the field is blank. To choose a channel, select it from the list. That port will be scanned for an interface. Successful communication with an interface is shown by the identifying information; here, a ULI 2 is connected to COM1. Click on OK to confirm the search and close the dialog. The next time Logger *Pro* is started the selected port will be used. If no interface is detected on the selected port, the OK button will change to Scan Port. Use this

button to re-scan the currently selected port, or click Cancel to leave the dialog without searching for an interface.



It is only necessary to use this dialog if Logger *Pro* is started without the interface connected or powered, or if communication with the interface is lost.

Window menu



New Tall Window →

New Tall Window creates a new window. The current window is halved in width and the new window is created beside the resized active window. A hierarchical menu, New Window has the following choices:

- Graph: Choose Graph to create a data plot.
- Table: Choose Table to create a new data table.
- FFT: Choose FFT → Graph to create a new Fast Fourier Transform graph, or subsequently FFT Table to create an FFT table.
- Histogram: Choose Histogram → Histogram Graph to create a new Histogram, or choose Histogram → Histogram Table to create a data table of the histogram bin counts.
- Text: Text opens a text edit window for comments.
- Meter: Meter creates a window with digital readouts of data.
- Chart Recorder: This feature is not available in the current version of Logger *Pro*.

New Window Wide →

New Window Wide creates a new window. The current window is halved in height and the new window is created below the resized active window. New Menu Wide has the same hierarchical choices as the New Tall Window command above.

Replace Window →

Replace Window also shares the hierarchical choice of the above commands, but instead of generating an additional window, it replaces the current window with the selected type of window.

Arrange

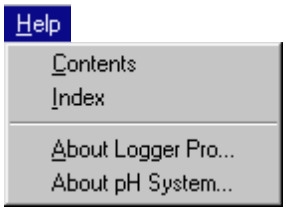
This feature is not available in the current version of Logger *Pro*.

Autotile — Autotile is a toggled setting. When checked it forces a tiled layout of windows whenever a window edge is moved.

Toolbar — Toolbar is a toggled setting. When checked the toolbar is visible on screen. Uncheck it to hide the toolbar.

1 Table Window — The title of each open window is listed at the bottom of the Window menu. Select the title of the window you want on top.

Help menu



Contents — Help Contents displays the table of contents for on-line help.

Index — Index displays the on-line help index.

About Logger *Pro* — About Logger *Pro* shows the version number and copyright information.

About (pH System) — The menu name will change to match the current experiment file. Choosing this item will open a text entry region for storing notes about the experiment file. When an experiment file with notes entered here is opened the notes will be displayed.

Appendix A
Troubleshooting Guide

Problem	Cause	Solution
Logger *Pro* cannot find the Interface	ULI or Serial Box Interface not correctly connected to computer	Connect interface to the modem or printer port (Macintosh) or COM1, COM2, COM3 or COM4 (PC) using supplied cable.
	Two or more copies of Logger *Pro* running	Exit all but the first copy of Logger *Pro*.
	Bad interface cable	Replace interface cable
	Wrong serial port being used	Make sure you are using the correct serial port. For example, don't confuse COM1 and COM2 (PC) or the Printer and Modem ports (Mac).
	Interface not receiving power (green light off) or not turned on.	Make sure the power adapter is plugged into a wall socket and connected to the interface. Turn on power switch (ULI only).
	Battery-powered Serial Box has dead batteries	On the Serial Box Interface, make sure the green LED comes on when you start up Logger *Pro*.
	Modem port of Macintosh not available	If you are using a Macintosh with an internal modem, make sure that the control panels are set for external modem. If you are using a Macintosh PowerBook with a single modem/printer port and are not using Ethernet port, AppleTalk must be turned off to make port available.
	Computer's serial port is set up for internal modem use. (This is a potential problem for any computer with an internal modem.)	Reconfigure the serial port for use with an external modem.
	Serial port of PC disabled	If you are using a laptop PC, make sure the serial port is not disabled by a power-saving mode.
	Modem or serial port in use by another program	Quit any other program that could be using the port.

Problem	Cause	Solution
The mouse locks up as Logger Pro starts up	Logger Pro and a serial mouse conflict (PC)	Hold down the Ctrl key during start up. The program will not automatically search for the interface. Click on the correct COM port for the ULI.
Cannot save a previously opened experiment file	File has been opened in read-only mode (default).	Clear read-only check-box when first opening file, or save the altered file under a new name.
Sensor not working	Sensor connected to the wrong port.	Make sure the sensor is connected to the correct connector. Refer to the Sensor Setup in Logger *Pro*.
	Two sensors connected to the same input line of the ULI.	Never use more than one sensor connected to each voltage input at the same time. For example, if you are using the DIN 1 socket, do not use the Port 1 modular phone connector at the same time.
	Sensor faulty	Try a different sensor. You might want to try measuring the voltage of a battery with the Voltage Probe.
No data appearing in graph	Graph range defined too small for data to appear	Select Autoscale or double-click on the graph and select a larger range of values for the axes.
Readings are noisy	Interface is picking up interference from the computer	Place the interface at least 30 cm away from the computer.

Appendix B
Using Logger *Pro* on a Network

General principles

If your computers are served software from a central file server on a network, you can install Logger *Pro* on the server. Create a folder on the server to hold Logger *Pro* (you will need sufficient privileges[7] to do this). Run the Logger *Pro* Installer from the floppy disk, and specify the file server folder when the installer asks for the desired location for Logger *Pro*. Set the student access rights to the Logger *Pro* folder to read-only and shareable. Then students can see and run Logger *Pro*, but cannot change it.

Logger *Pro* preferences

Logger *Pro* will read a preferences file in its own directory on startup. This file indicates the location all calibration files and the default location of experiment files. If you want students to use a standard set of calibration and experiment files, the files should be stored on the server in a location to which students have the same access privileges as the Logger *Pro* program itself. The preferences must then be set to indicate the location of these files on your server. When you set the preferences, you must have write access to make changes to the preferences, experiment, or calibration files.

Two good choices for the location of experiment files are 1) A protected directory on the file server where the students cannot make changes; or 2) A local directory where students can store their own files. In the first case students must be directed to save files to another directory; in the latter, experiment files must be placed on each computer and could be changed inadvertently. To avoid accidental changes, set file attributes to Read-only (Windows, right-click on file to see dialog) or to Locked (Macintosh, select file, choose Get Info to see dialog). This way you can have a reference set of experiment files while students can still save their own files.

Similarly, calibration files can be stored either centrally on the server or on individual machines. If your students will use a common set of calibration files, then choose the former. For the less common case of individually calibrated sensors (custom calibration done for a specific sensor/interface/computer combination), then the calibration files must be stored locally since they will be different for each computer. Lock or set to read-only those files you do not want changed.

Macintosh

To use the network copy of Logger *Pro* on networked computers, log in to the file server so the server's icon is on the Macintosh desktop. Locate the Logger *Pro* icon, and double-click to start. For simplicity, create an alias for Logger *Pro* on the local hard disks. Then, when the alias is double-clicked, the user will be prompted to log in, the file server disk will be mounted and Logger *Pro* will start.

Windows

To use the network copy of Logger *Pro* on networked computers, log in to the file server and navigate to the Logger *Pro* icon. Double-click on it to start. As a shortcut in Windows 95, you may want to drag the Logger

[7]File servers provide some security by only allowing certain users to perform functions like saving, modifying, or deleting files in certain directories. Typically only administrative accounts are allowed to make changes anywhere on the server—one speaks of having the *privilege* or *right* to make these changes.

Pro icon to the Start menu to place Logger *Pro* in the Start menu list. In Windows 3.1x you can create a program group and item for Logger *Pro*.

Student use of Logger *Pro* on a network

For your students to use Logger *Pro* on a network, they first must have adequate access rights. Student access should allow Logger *Pro* to be seen and executed, but not changed in any way. Your network administrator should be able to assist in this setting.

Appendix C
Interfaces Compatible with Logger *Pro*

ULI or Serial Box Interface?

You can use either the Universal Lab Interface (ULI) or the Serial Box Interface with Logger *Pro*. The two interfaces differ in capability, but often either can be used. While the ULI can do almost everything the Serial Box Interface can do while adding higher speed and digital inputs, the ULI is more expensive. The table below will give you the details so you can decide which interface to use in your experiments.

Interface	Cost	Data Rate	Sensors	Use in…
Serial Box Interface	$99 $59 for Logger *Pro* software or $30 for Data Logger (both include site license)	As fast as 50 readings per second	Two analog inputs to use with temperature, voltage, pH, pressure, force, colorimetry, light, heart rate, EKG, dissolved oxygen, conductivity, magnetic field, and others.	Chemistry Biology Physical Science Middle School Integrated Science Earth Science
Universal Lab Interface	$299 $59 for Logger *Pro* software or $49 for ULI Software Package[8] (both include site license)	As fast as 11,000 readings per second	Four analog and two digital ports to use with all of the above *plus* motion, ULI Force, photogate, radiation	all of the above *plus* Physics

Battery operation

The Serial Box Interface offers the advantage of battery operation. The Smart Battery Holder (SBI-BAT, $29) allows battery operation of the Serial Box Interface, and is an ideal match to a portable computer for field work.

[8]Contains Data Logger, Motion, and Sound for Macintosh or MS-DOS, plus ULI Timer (Mac only) .

Appendix D
Sensors for use with Logger *Pro*

You can use many different Vernier sensors with Logger *Pro*. The Logger *Pro* package includes calibration files for these sensors. Most sensors can be used with either the ULI or the Serial Box Interface; others can be used only with the ULI.

Sensors supported by both the Serial Box Interface and ULI

These sensors can be used with Logger *Pro* and either a Serial Box Interface or a ULI:

- 25-g Accelerometer
- Barometer
- Biology Gas Pressure Sensor
- CO_2 Gas Sensor
- Colorimeter
- Conductivity Probe
- Direct-Connect Temperature Probe
- Dissolved Oxygen Probe
- Dual-Range Force Sensor
- EKG Sensor
- Exercise Heart Rate Monitor
- Extra Long Temperature Probe
- Flow Rate Sensor
- Heart Rate Monitor
- Ion-Selective Electrodes
- Light Sensor
- Low-g Accelerometer
- Magnetic Field Sensor
- pH System
- Pressure Sensor
- Relative Humidity Sensor
- Standard Temperature Probe
- Student Force Sensor
- Thermocouple
- Voltage Probe

Sensors for the ULI only

In addition, if you are using the ULI, you can also use the following sensors.

- Motion Detector
- ULI Force Probe
- Radiation Monitor or Student Radiation Monitor

- Rotary Motion Sensor
- Microphone
- 3-Axis Accelerometer

Experiment and calibration files

Experiment files for all supported sensors are supplied with the Logger *Pro* package. These experiment files will automatically load Vernier calibration files for use with these sensors, although other calibration files may be chosen.

After loading a sensor's experiment file, Logger *Pro* will display appropriate units for that sensor.

Additional Sensor Information

The remainder of Appendix D consists of a list of sensors compatible with Logger *Pro*, accompanied by short descriptions of their capabilities.

Sensor data sheets

Each Vernier sensor is sold with a comprehensive data sheet which explains specific sensor characteristics, gives calibration information, and suggests experiments to be performed. Consult the data sheet for the particular sensor for additional information.

25-g Accelerometer

Our 25-g Accelerometer is great for studying collisions or centripetal acceleration and any situation with fairly large accelerations. Range $\pm$ 250 m/s^2 ($\pm$ 25g).

3-Axis Accelerometer

Our 3-Axis Accelerometer is really three low-g accelerometers mounted at right angles and all placed in a small box. Use it for studying the complex motion of an amusement park ride, a bungee jumper, or simply a toss in the air. With most our data collection programs, you can graph the magnitude of the acceleration vector.

Barometer

Our Barometer can be used for weather studies or for lab experiments involving pressures close to normal air pressure. The pressure range is 24 to 32 inches of Hg (0.8 to 1.05 atm) absolute pressure.

Biology Gas Pressure Sensor

Use the Biology Gas Pressure Sensor to monitor gas-pressure changes due to respiration or transpiration. It can also be used as a standard barometer for monitoring air pressure. It can even be used to investigate pressure-volume or pressure-temperature experiments in chemistry. This sensor has a pressure range of 0.75 to 1.5 atm.

CO_2 Gas Sensor

The CO_2 Gas Sensor measures gaseous carbon dioxide levels in the range of 0 to 5000 ppm. This probe is great for measuring changes in CO_2 levels during plant photosynthesis and respiration. With this sensor, you can easily monitor changes in CO_2 levels occurring in respiration of organisms as small as crickets or beans! The CO_2 Gas Sensor is easily calibrated using a calibration button. A chamber with probe attachment is included for running controlled experiments with small plants and animals.

Colorimeter

This is a 3-color (red-635 nm, green-565 nm, blue-470 nm) colorimeter. It is great for Beer's law experiments, determining the concentration of unknown solutions, or studying changes in concentration vs. time. Fifteen 3.5-mL cuvettes are included. A package of 100 replacement cuvettes is available.

Conductivity Probe

Excellent for environmental testing for salinity, total dissolved solids (TDS), or conductivity in water samples. Biology teachers can use this sensor to demonstrate diffusion of ions through membranes or to

monitor changes in ion levels in aquatic systems. Chemistry students can use it to investigate the difference between ionic and molecular compounds, strong and weak acids, or ionic compounds that yield different ratios of ions. The Conductivity Probe can monitor concentration or conductivity at three different sensitivity settings covering 0-10,000 mg/L TDS (0-20,000 µS).

Current & Voltage Probes System

Use our Current & Voltage Probes to monitor currents and voltages in DC and AC circuits with the ULI, SBI, or CBL. The system consists of an amplifier box, two current probes, and two voltage probes. Any combination of two probes can be used at once. The voltage range is ±6 V (wider than with our Voltage Probe) and is a true differential input. The current range is ±0.6 A.

Direct-Connect Temperature Probe

This is our most popular temperature probe. It has a Teflon-coated brass tube with a temperature sensor at the end. It can be used in a wide variety of chemicals with a temperature range of –15 to 110°C (±0.2°C in normal use).

Dissolved Oxygen Probe

Use the Dissolved Oxygen Probe to determine the concentration of oxygen in aqueous solutions in the range of 0-15 mg/L (ppm). It has built-in temperature compensation and a fast response time This sensor is great for biology, chemistry, ecology, or integrated science courses. Included with the sensor is an amplification box, zero-oxygen solution, two membrane caps, a 100% calibration bottle, and electrode filling solution. Replacement membrane caps are available.

Dual-Range Force Sensor

This low-cost force sensor has two ranges. It can be easily mounted on a ring stand or dynamics cart, or used as a replacement for a hand-held spring scale. Use it to study friction, simple harmonic motion, impact collisions, or centripetal force. It can be used with any of our lab interfaces or CBL.

EKG Sensor

The EKG Sensor measures electrical signals produced by the heart. It uses three disposable electrode patches. An EKG graph is displayed, demonstrating to students the contraction and relaxation of the heart's chambers. A package of 100 disposable electrodes is included with the sensor.

Exercise Heart Rate Monitor

The Exercise Heart Rate Monitor is ideal for determining the heart rate of moving or active individuals. With this sensor, a person's heart rate can be monitored during, as well as after exercise. The Exercise Heart Rate Monitor consists of a wireless transmitter belt and a receiver module that plugs into a Vernier interface box or CBL. The transmitter belt senses the electrical signals generated by the heart much like an EKG. For each heart beat detected, a signal is transmitted to the plug in the receiver module, and a heart rate is determined.

Flow Rate Sensor

The Flow Rate Sensor is used to measure stream velocity for environmental or earth science studies. Using flow rate data, your students will be able to calculate discharge value for the stream in ft^3/s or m^3/s, or determine the sediment transport of the stream. The impeller rod separates into four sections for easy transport and convenient storage. The Flow Rate Sensor comes equipped with a five-meter cable so your data collection equipment can stay on shore while you measure flow rate in the stream. Three riser rods are included with each sensor, which enable the impeller to be placed at fixed depths.

Heart Rate Monitor

The Vernier Heart Rate Monitor measures human pulse rate. Simply attach the Heart Rate Monitor's earclip to your ear lobe, and your pulse rate is displayed on the computer monitor. Heart Rate Monitor program (Macintosh or MS-DOS versions included free on the Data Logger disk)

displays the heart-beat waveform, pulse rate in beats/minute, data table, statistics, and a graph of pulse rate vs. time.

Instrumentation Amplifier

The Instrumentation Amplifier will monitor voltages from a few millivolts (DC or AC). It has several ranges to allow you to select the most appropriate gain: 0-20 mV, 0-200 mV, 0-1 V, ±20 mV, ±200 mV, and ±1 V. The amplifier has a true floating differential input, unlike the DIN ports of the ULI. It can be used with any of our computer lab interfaces, as well as the Texas Instruments CBL.

Ion-Selective Electrodes

We have a family of solid-state and PVC membrane ion-selective electrodes: Nitrate (NO_3^-), Chloride (Cl^-), Calcium (Ca_2^+), and Ammonium (NH_4^+). These electrodes require the Ion-Selective Electrode Amplifier (ISE-DIN) for connection to the ULI.

Light Sensor

Our Light Sensor approximates the human eye in spectral response and can be used over three different illumination ranges, which you select with a switch. Use it for inverse square law experiments or for studying solar energy. The ranges are 0-600, 0-6000, 0-150,000 lux.

Low-g Accelerometer

This sensor measures acceleration in the range of ±50 m/s^2 (±5 g). It has a flexible 2-meter cable. It is useful for studying motions with smaller accelerations, like cars (real and toy), elevators, and amusement park rides.

Magnetic Field Sensor

This sensor, which uses a Hall Effect transducer, is sensitive enough to measure the earth's magnetic field. It can also be used to study the field around permanent magnets, coils, and electrical devices. Its two ranges are $\pm 3.2 \times 10^{-4}$ tesla and $\pm 6.4 \times 10^{-3}$ tesla.

Motion Detector

The Motion Detector functions like the automatic range finder on a Polaroid camera. This sonar device emits ultrasonic pulses at a rate adjustable between 10 and 50 times per second. The time it takes for the reflected pulse to return is used to calculate distance, velocity, and acceleration. The range is 0.5 to 6 meters. We have versions for use with the MPLI, ULI or CBL.

pH System

Our pH System includes a pH Electrode and pH Amplifier. The pH Electrode is a Ag-AgCl combination electrode with a range of 0 to 14 pH. The pH Amplifier contains the signal-conditioning circuitry. The Electrode is also available separately.

Pressure Sensor

Our Pressure Sensor has a range of 0 to 100 psi (0 to 6.8 atm) absolute pressure. It is designed for gas law experiments in chemistry, physical science, and physics. A plastic syringe and tubing are included for use with Boyle's law experiments.

Radiation Monitors

The Radiation Monitor was adapted for the Workshop Physics courses at Dickinson College. It consists of a Geiger-Mueller tube and rate meter mounted in a small, rugged, plastic case. The unit is battery operated and can be used with or without a computer for measurement of alpha, beta, and gamma radiation.

We also have a low-cost Student Radiation Monitor for monitoring beta and gamma radiation. It consists of a Geiger-Mueller tube mounted in a small, rugged case. It can be used to measure the total number of counts per specified timing interval. Your students can investigate topics such as shielding, inverse square law, and half-life.

Relative Humidity Sensor

The Relative Humidity Sensor contains an integrated circuit that can be used to monitor relative humidity over the range 0 to 95% (±5%). Use this sensor for weather studies, monitoring greenhouses, or for determining days when static electrical discharges could be a problem.

Respiration Monitor Belt

Our Respiration Monitor Belt is used together with our Biology Gas Pressure Sensor to measure respiration. Simply strap the belt around your chest, then pump air into the belt with the hand bulb, providing as much pressure as desired. You can then monitor the pressure associated with the expansion and contraction of the chest during breathing. This accessory is great for biology, physiology or life science courses. Requires the BGP-DIN sensor.

Rotary Motion Sensor

The Rotary Motion Sensor monitors angular position with a resolution of 0.25 degrees. The sensor is direction sensitive. Logger *Pro* will calculate angular velocity and acceleration from the position data. Linear position can also be measured to sub-millimeter resolution.

Standard Temperature Probe System

This system has a signal-conditioning box and probe with the same Teflon coating as the Direct-Connect Temperature Probe. The system has a range of –50 to 150°C. The probe can be disconnected from the box and replaced with a variety of replacement temperature probes:

- Standard Temperature Replacement Probe
- Quick-Response Temperature Replacement probe. The smaller, ceramic sensor for this probe means the probe can respond more quickly to changes in temperature. It is, however, much less protected, both chemically and physically. We recommend it for air and water only and in situations where extremely quick response is necessary.
- Extra Long Temperature Probe. See the description of this probe below.

Extra Long Temperature Probe

This is the same as our Standard Temperature Probe System, but the probe has a 30-meter (100 ft) cable. This probe is designed for remote, outdoor temperature sensing or for measuring temperature at various depths in lakes or streams.

Thermocouple

This sensor uses type-K thermocouple wire to measure the difference in temperature between its two junctions. It can be used over the range –200 to 1400°C (±10°C). It can be used to study flame temperatures.

Student Force Sensor

This strain gage force measurement device can measure forces from 0.05 to 10 newtons or more (push or pull). The range can be changed by adjusting a screw. It can be mounted on a ring stand or used as a replacement for a hand-held spring scale. Use it to study friction, simple harmonic motion, impact in collisions, or centripetal force.

Voltage Probe

One set of test leads with red (positive) and black (ground) leads is included with the Serial Box Interface and the ULI. Use these leads for direct voltage measurement.

Sensor Price List

Sensor/Probe	Price/Order Code
25-g Accelerometer	$99 (ACC-DIN)
3-Axis Accelerometer	$199 (3D-DIN)
Barometer	$56 (BAR-DIN)
Biology Gas Pressure Sensor	$68 (BGP-DIN)
CO_2 Gas Sensor	$259 (CO2-DIN)
Colorimeter	$99 (COL-DIN)
Conductivity Probe	$79 (CON-DIN)

Current & Voltage Probes	$84 (CV-DIN)
Direct-Connect Temperature Probe	$28 (DCT-DIN)
Dissolved Oxygen Probe	$189 (DO-DIN)
Dual-Range Force Sensor	$98 (DFS-DIN)
EKG Sensor	$175 (EKG-DIN)
Exercise Heart Rate Monitor	$89 (EHM-DIN)
Extra Long Temperature Probe	$68 (TPL-DIN)
Heart Rate Monitor	$47 (HRM-DIN)
Ion-Selective Electrode Amplifier	$39 (ISE-DIN)
Ion-Selective Electrodes (requires ISE-DIN) (NO_3^-, Cl^-, Ca^{2+}, NH_4^+)	$149 each
Instrumentation Amplifier	$49 (INA-DIN)
Light Sensor	$39 (LS-DIN)
Low-g Accelerometer	$88 (LGA-DIN)
Magnetic Field Sensor	$44 (MG-DIN)
Motion Detector	$65 (MD-ULI)
pH System	$72 (PH-DIN)
Photogate Parts Kit[9]	$9 (PGK-DG)
Pressure Sensor	$69 (PS-DIN)
Radiation Monitor	$199 (RM-DG)
Relative Humidity Sensor	$65 (RH-DIN)
Respiration Monitor Belt (Requires Biology Gas Pressure Sensor)	$58 (RMB)
Rotary Motion Sensor	$185 (CI-6625)
Standard Temperature Probe	$43 (TPA-DIN)
Student Force Sensor	$99 (SFS-DIN)
Student Radiation Monitor	$138 (SRM-DG)
Thermocouple	$35 (TCA-DIN)
ULI Force Probe	$130 (FP-ULI)
ULI Microphone	$30 (MCA-ULI)
Vernier Photogate (Assembled)	$39 (VPG-DG)
Voltage Probe (One included with ULI)	$7 (TL-DIN)

[9]For a ULI purchased prior to 1995, order the 2-Photogate Parts Kit (2PUL, $38).

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