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CANdaq

Data Filtering and Averaging

(Including CANdaq Filter Simulator Userguide)

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900095-1.0

Please read this manual carefully before using the instrument.

Use of this equipment in a manner not specified in this manual may impair the user's protection.

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Chell's policy of continuously updating and improving products means that this manual may contain minor differences in specification, components and circuit design from the actual instrument supplied.

CONTENTS

1. Introduction.

CANdaq offers a number of signal processing options to the user within its onboard software, both to reduce any signal noise content, and to enable the averaging of input data.

Impulse filters on both pressure and temperature inputs allow the removal of isolated noise spikes, and two data averaging filters (one before and one after the pressure signal calibration) allow the user to set the unit's pressure signal response characteristic. For temperature compensated calibrations, the scanner temperature signal is passed through another data averaging filter.

The arrangement of the signal processing elements is shown in Figure 1.1.

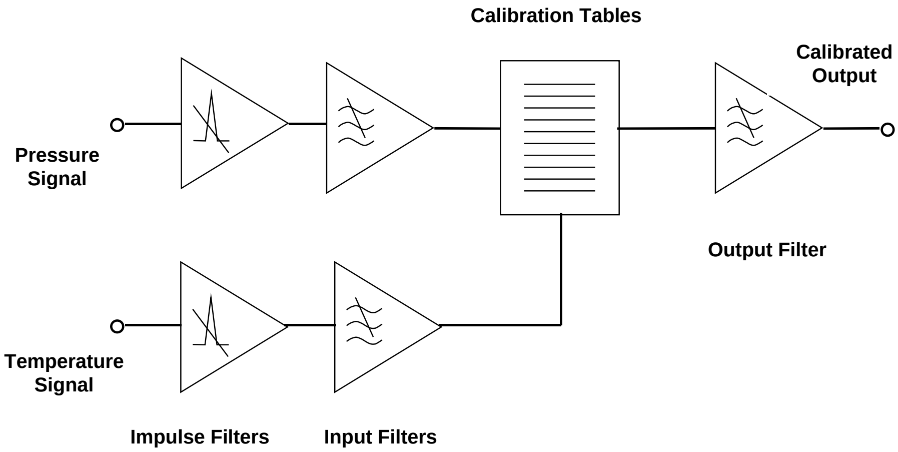

Figure 1.1, Arrangement of CANdaq's Signal Processing Elements.

The following provides examples of the operation of the filters on simulated data, as well as calculated frequency and phase responses for the filters.

2. Impulse Filters.

2.1 Removal of impulsive noise.

Impulse filters are available on both pressure and temperature signals from the ESP scanner. The only option available to the user is ON/OFF, the scope of the filter being predetermined in the CANdaq firmware. The filters will remove completely a single isolated datum that lies outside the current acquired signal envelope, at the expense of a single sample phase delay. There is no other degradation of the signal, and the response is frequency independent. Figure 2.1 shows a plot of a simulated signal before and after passing through the impulse filter, showing the sparse impulse noise removed almost in its entirety.

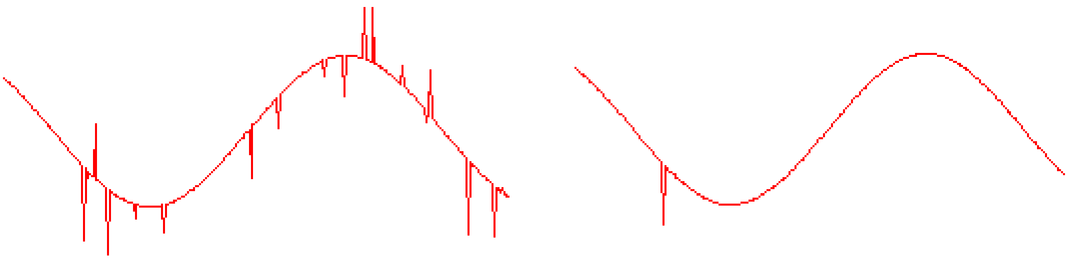

Figure 2.1, Operation of the impulse filter on isolated noise data. Noisy input (left), resulting output (right) showing the majority of noise removed.

Note that although the majority of the impulsive noise on the input signal is successfully removed by the filter, in this example a single noise datum passed. This is due to it being part of a noise 'burst' of more than a single sample, which the filter is incapable of removing. Figure 2.2 shows the action of the filter on simulated data with a more frequent noise impulse content.

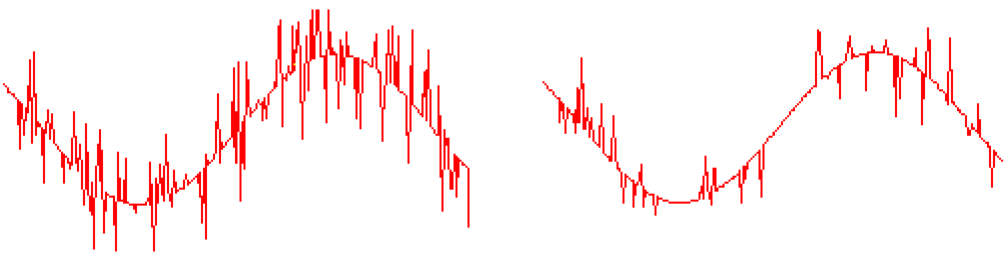

Figure 2.2, Operation of the impulse filter on data with a freqent noise impulse. Input (left) and output (right).

Althought the noise content of the data input is seen to be thinned out by the impulse filter, noise bursts are seen to pass through to the output. Due to the filter's unhindered step response, impulses passing through the filter are unattenuated. For a noisy signal of the kind shown in figure 2.2, the user would be well advised to add additional data averaging to attenuate the noise.

2.2 Phase Response.

As stated above, the only trade off in the use of an impulse filter on the data from CANdaq is the introduction of a single sample phase delay. In the case of the impulse filter, as with other signal processing on CANdaq, the data sampling rate is a function of the number of active channels read from the scanner. This is not the number of channels selected for delivery on a particular channel (eg TCP/CAN/RS232), rather the maximum number of channels set up to be used by CANdaq.

Since the scanner is always accessed at its maximum channel rate of 20kHz, the actual data sampling rate ranges from 312.5Hz (64 channels), through 625Hz (32 channels) to 1250Hz (16 channels). This would correspond to single sample phase delays for the impulse filter of 3.2ms, 1.6ms and 800us respectively.

3. Input and Output Data Averaging Filters.

3.1 Overview.

The pressure signal path within CANdaq has the option of two data averaging filters, one before and one after the signal calibration. In all other respects the filters are identical.

The 'input' filter feeds the acquired and averaged pressure signal into the calibration calculation, which is then connected directly into the 'output' filter. The calibrated and averaged data is then available to the data delivery services.

The user is able to choose the number of samples that form the basis of the average that forms the filter output. The choice is made from a selection of values in the CANdaq setup software, all powers of two allowing the efficient coding of the filters within the firmware. The response is that of a simple low pass filter, so by judicious choice of the number of samples the user may either add a degree of band limiting to remove the higher frequency noise components from a signal, or for higher numbers of samples, the data may be averaged to give a slow moving representation of the pressure signal.

3.2 Frequency Response.

Figures 3.1, 3.2 and 3.3 show the determined frequency response for the data averaging filters (both input and output). The graphs show responses for active channel numbers of 16, 32 and 64 respectively, as following the same argument as for the phase delay of the impulse filters, the actual data sample rate is dependent on the number of channels (20kHz/no. channels).

Each plot shows the response for a number of settings of the number of samples. The response for 'off' is the flat response of gain = 1 for all frequencies. For two samples, the response is shown by the rightmost curve of the graphs, the response for four samples the next curve to the left and so on, increasing the number of samples by powers of two moving across the response curves.

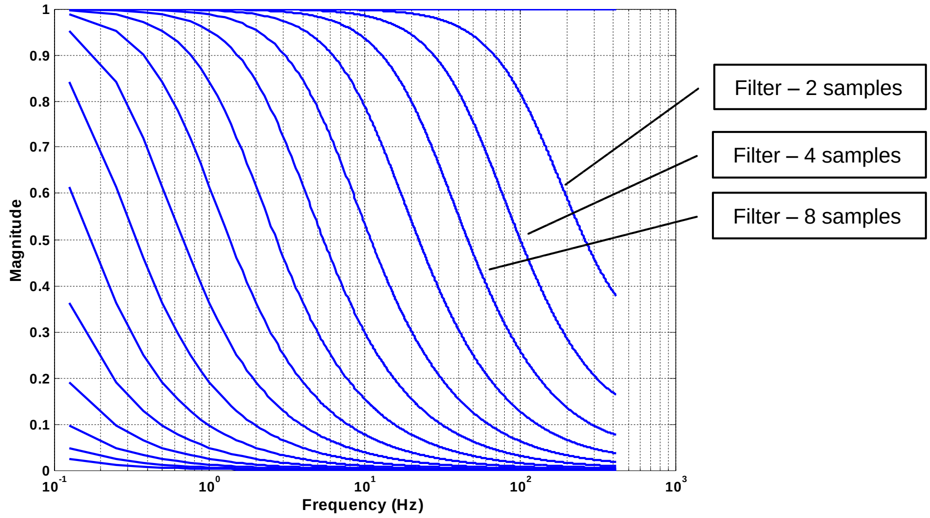

Figure 3.1, Frequency Response for Data Averaging Filter – 16 Channels.

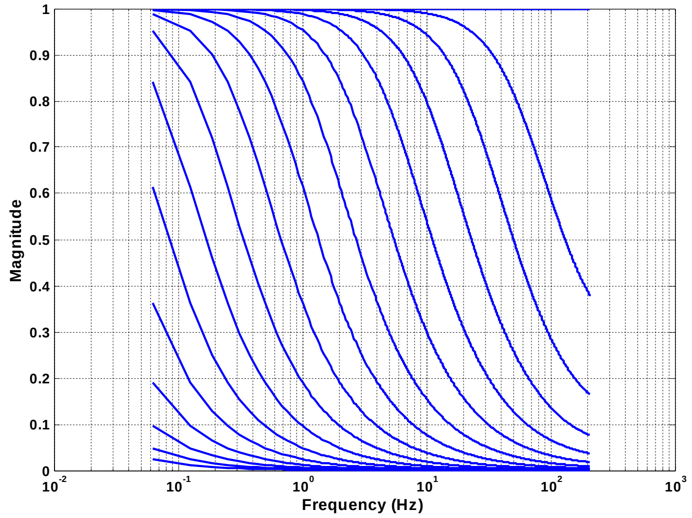

Figure 3.2, Frequency Response for Data Averaging Filter – 32 Channels.

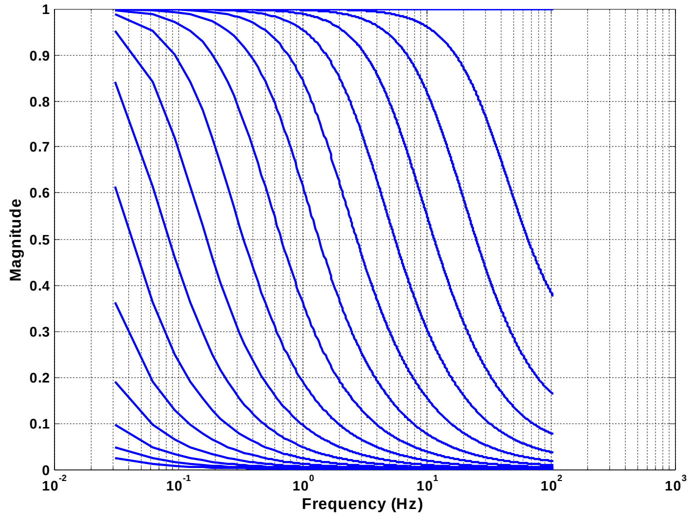

Figure 3.3, Frequency Response for Data Averaging Filter – 64 Channels.

3.3 Phase Response.

The corresponding phase responses for the averaging filters are shown in figures 3.4 to 3.6.

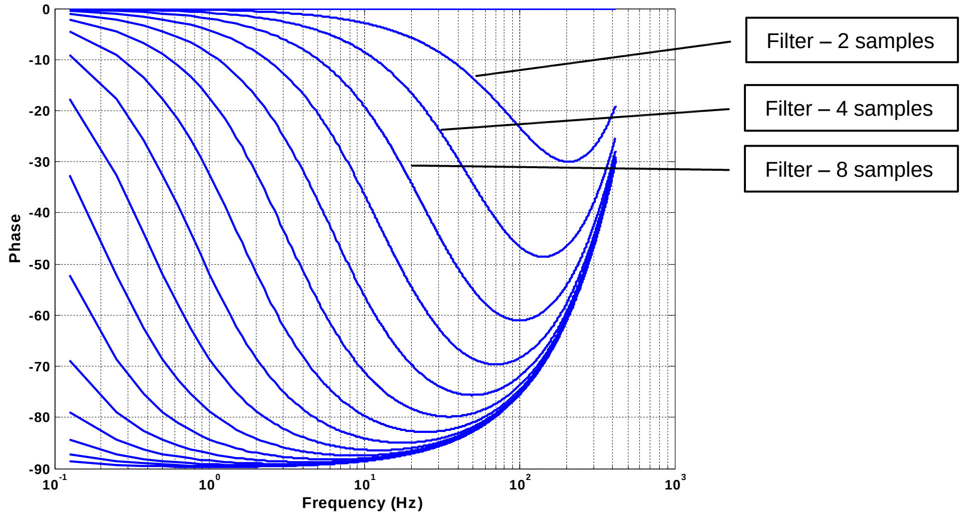

Figure 3.4, Phase Response (degrees) for Data Averaging Filter – 16 Channels.

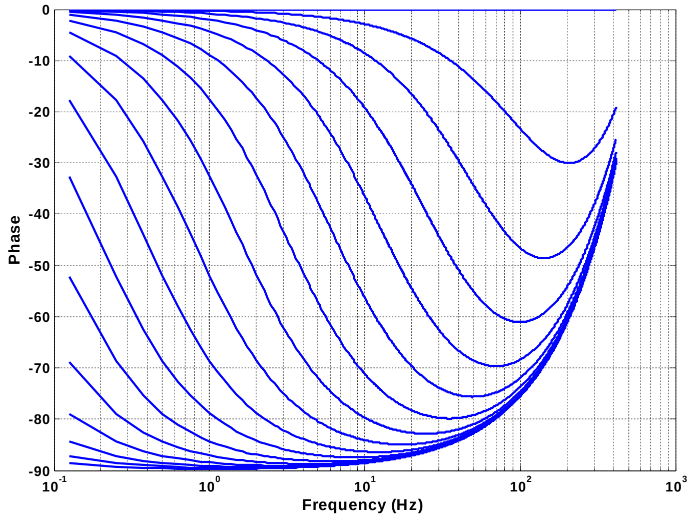

Figure 3.5, Phase Response (degrees) for Data Averaging Filter – 32 Channels.

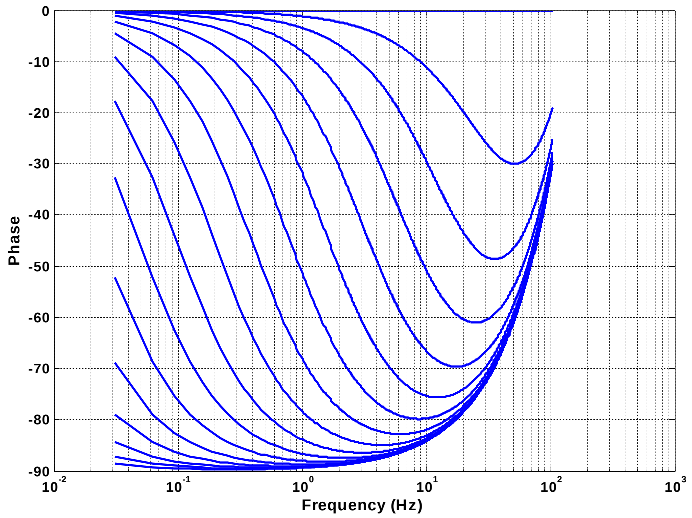

Figure 3.6, Phase Response (degrees) for Data Averaging Filter – 64 Channels.

3.4 Time Domain Step Response.

The implication of the limited frequency response is most obvious in the step response of the filter, the resulting output from the application of a perfect step transition to the input of the filter as seen in the time domain.

Figure 3.7 shows the typical response of the averaging filter to an applied square wave for both low and higher numbers of data averaging points. The first diagram shows a milder example of the band limiting effects from a lower number of data samples in the average filter.

Figure 3.7, Bandlimited Output in the Time Domain for a Square Wave Input, Lower and Higher Number of Samples.

Applications requiring a fast response to an event should maintain low values for the data averaging filters in order to maintain the fast time response. The time domain response curves for different numbers of active channels are shown in figures 3.8 to 3.10.

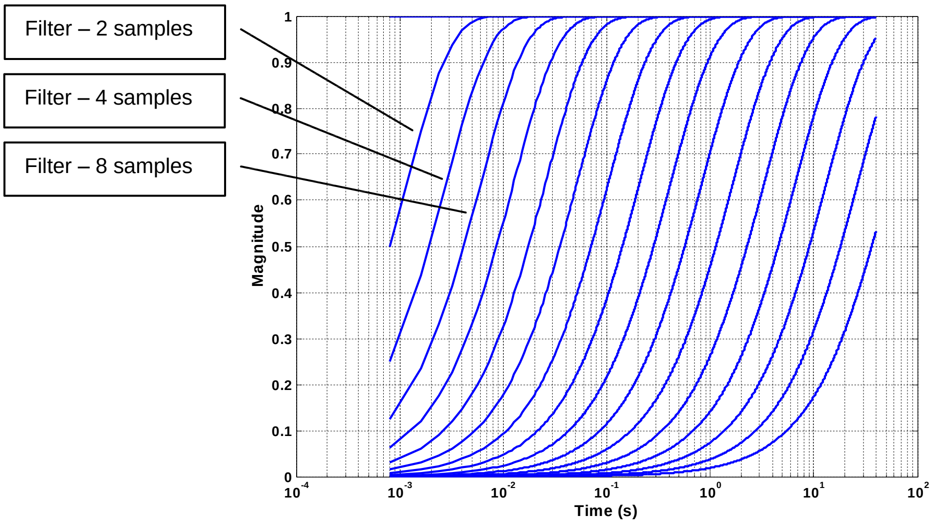

Figure 3.8, Time Response of a Data Averaging Filter for a Unit Step Input – 16 Channels.

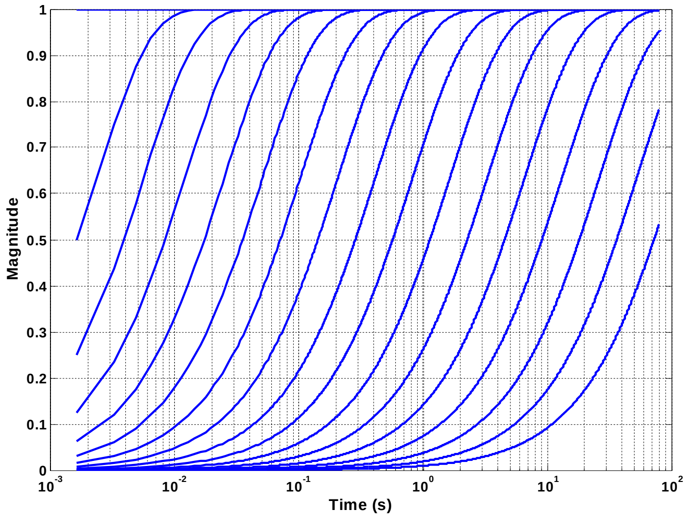

Figure 3.9, Time Response of a Data Averaging Filter for a Unit Step Input – 32 Channels.

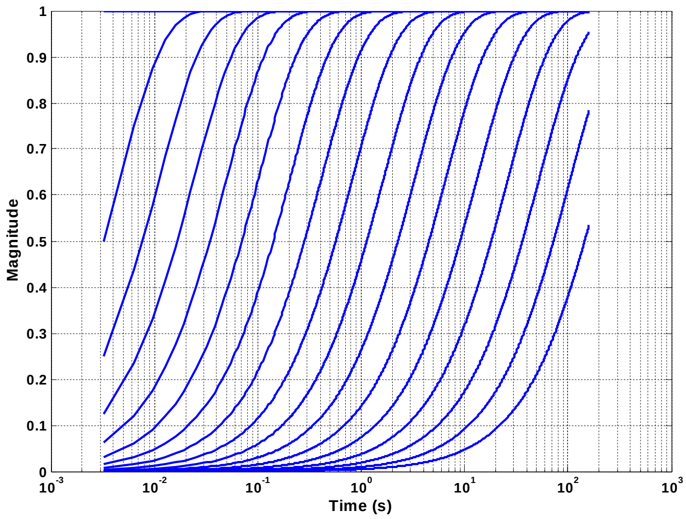

Figure 3.10, Time Response of a Data Averaging Filter for a Unit Step Input – 64 Channels.

4. Combining Filter Elements.

The above details the individual responses of CANdaq's filtering elements, however in reality it is more likely that the filtering will be applied simultaneously by all elements. When considering the combined effect of both data averaging filters, it should be borne in mind that the overall response of the two concatenated filters is the product of the two filter magnitudes, and the sum of the two phases. If the impulse filter is also applied to the data, then its single data sample delay will be added to the overall phase delay of the filters.

5. Temperature Signal Filtering.

For temperature compensated calibrations, the temperature signal from the scanner is used to generate the calibration tables for CANdaq. It is important that this signal is particularly stable and noise free as a corrupt or otherwise incorrect value of temperature will lead to erroneous calibrated output until the table is rebuilt by the compensation software.

For this reason it is recommended that the temperature input should always have the impulse and data averaging enabled.

6. CANdaq Filter Simulator.

6.1 Overview.

CANdaq Filter Simulator is a software application that allows the simulation and assessment of the effects of CANdaq's data filtering software on an acquired signal. A user may build an arbitrary periodic signal with up to three sine and square wave components with selectable amplitude, period and phase specifications.

Noise may be added using a statistical measure, with up to three noise components of differing amplitude and probability. Two plot windows show the raw data signal with the input signal to the calibration tables, and the resulting signal after the calibration and output filter. At present the calibration is represented by a linear multiplication.

Time based measuring cursors allow the determination of signal characteristics, and the software attempts to automate the measurement of overall gain (factored for the calibration multiplication) and phase delay of the signal. Note that the application is intended as an engineering tool and as such a degree of user interaction and interpretation is required in order to avoid unexpected results.

6.2 The User Interface

Figure 6.1 shows the CANdaq Filter Simulator user interface, with an arbitrary signal and response shown. The effect of the raw data filtering (ie the impulse filter and input averaging filter) may be seen in the upper plot window with the removal of noise at the expense of some of the higher frequency components, and a signal phase delay. The lower window shows the output data, further smoothed by the output data averaging filter.

The function of the form controls is detailed in table 6.1.

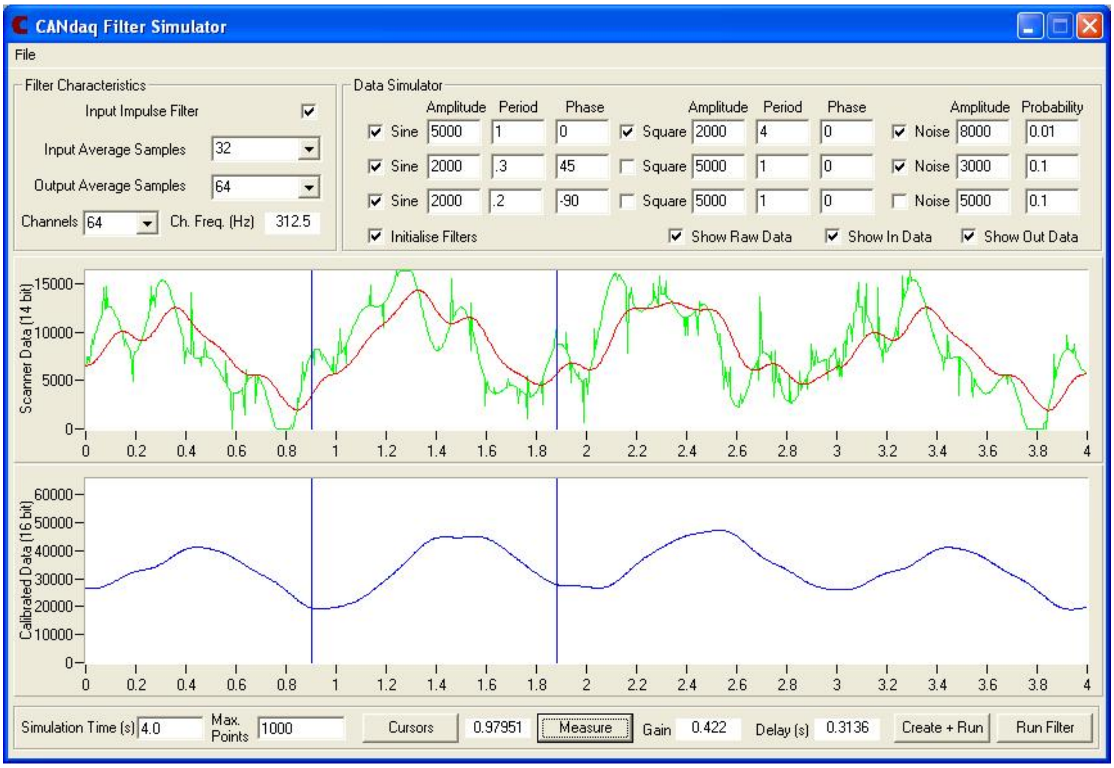

Figure 6.1, The User Interface to CANdaq Filter Simulator.

Control	Function
File Menu (Load/Save)	Save current settings for reuse, or reload previous simulations.
Input Impulse Filter checkbox	Impulse filter on/off.
Input Average Samples dropdown	Select the number of samples in the ‘input’ data averaging filter.
Output Average Samples dropdown	Select the number of samples in the ‘output’ data averaging filter.
Channels	Select the number of active channels on CANdaq – 64/32/16.
Ch. Freq. (Hz) label	Shows the channel frequency depending on number of active channels selected.
Sine checkbox	Include this specification sine wave in the raw data signal.
Square checkbox	Include this specification square wave in the raw data signal.
Noise checkbox	Include this specification noise in the raw data signal.
Amplitude	Peak value for a signal component, units of ADC counts.
Period	Time period for a signal component, units seconds.
Phase	Phase advance of the signal component, units degrees.
Probability	For noise signals, the probability (0 to 1) that a signal datum contains a noise component of random magnitude, with a maximum of the amplitude selected.

Show Data checkboxes	Signal plots on/off .
Initialise filters checkbox	Sets the filter output to match the input at time zero., otherwise the filter output initialises to its range midpoint.
Scanner Data	Plot window for the 14 bit simulated input data, and the resulting 14 bit ‘input’ data after filtering.
Calibrated Data	Plot window for the 16 bit calibrated data after the ‘calibration’ multiplication and ‘output’ filtering.
Simulation Time	Time (s) over which to perform the simulation.
Max. Points	Number of data points for resampling for display purposes.
Cursors button	Show the measurement cursors.
Cursors label	Shows the real time absolute difference in the cursor positions.
Measure button, Gain and Delay labels	Calculates the ratio of the peak to peak measurements of the raw and output signal between the cursors, factored for the calibration gain – ie a sine wave inputs with no filtering should show a gain of unity. The phase is measured as the time between the maximum value of raw data between the cursors, to the subsequent maximum in the output data. Use with care on simple waveforms only without noise for correct results.
Create and Run button	Create the raw data to the specification selected, and pass the data through the filter parameters chosen.
Run Filter button	Re run the same raw data through an altered filtering specification for comparison.

Table 6.1, Control Detail for CANdaq Filter Simulator.

6.3 Operation.

To use the simulator, the raw waveform components and filter settings should be chosen, then the ‘Create and Run’ button clicked. To observe the effect of an alternative filter arrangement on the output, make the alterations to the filter settings and click ‘Run Filter’. New data may be built at any time by adjusting the controls and clicking ‘Create and Run’.

To measure features in the waveforms, click ‘Cursors’ to view the measuring cursors. Each cursor may be dragged with the mouse, and the time calibrated distance between them is constantly updated on the form.

To perform a gain and delay measurement, create ‘clean’ data without noise components. Position one cursor in a trough of the raw data, and the other a single cycle or so further on in time. Click ‘Measure’ to determine the effective frequency response (maximum unity) and phase delay in seconds.