User guide for Vib4Ch_decimate program

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September 2010

1 Introduction

Vib4Ch_decimate.vi is a National Instruments (NI) LABVIEW program to use the 4 channel NI 9234 analogue input module for data acquisition and basic spectrum analysis. The NI 9234 has built in anti-aliasing filters on all channels, which make it particularly suitable for vibration measurements.

2 Requirements

The following is required:

- LABVIEW 2009 or a newer release needs to be installed on the computer to run Vib4Ch_decimate. The School of Engineering has a school-wide licence for LABVIEW and UP staff and students may use this for academic and research work. Contact the author to borrow the program DVD-s (see section 7).
- A NI 9234 module plugged into either a NI USB-9162 single module carrier or a NI cDAQ-9178 CompactDAQ chassis, either connected to the PC through a USB port. (In July 2010 the SASOL lab had three of the former and one (an 8 slot unit) of the latter.) The Vib4Ch_decimate.vi program has been written with a single NI 9234 analogue input module in mind, because at the time of writing this program, the SASOL lab had only one of these modules. It is interesting to note, though, that the using eight NI 9234 modules in a single NI cDAQ-9178 CompactDAQ chassis results in a simultaneously sampled 32 channel data acquisition system. The Vib4Ch_decimate.vi program can be easily expanded to accomodate more than four input channels when more than one NI 9234 analogue input module is available; see section 7.
- The Vib4Ch_decimate.vi program should be set up correctly for the hardware to be used. To check this, the vi should be opened by double clicking on it in Windows Explorer or by starting LABVIEW and then opening it as a vi. Once the front panel is displayed, the block diagram can be obtained by clicking anywhere in the front panel and then pressing Ctrl-E. (Ctrl-E toggles between the vi front panel and its block diagram.) In the block diagram double click on the DAQ Assistant (see figure 1). This will open a configuration window as shown in figure 2. In this window, "Voltage_0" refers to the 1st analogue input channel and "Voltage_3" to the 4th, etc. Check that the settings listed under the "Settings" tab is correct for all four channels by selecting them one-by-one by clicking on the channel in the list. (After selection the channel is highlighted in blue, as is the first channel in figure 2.) Also check the AC/DC coupling mode for each channel, under the "Device" tab.

  Lastly, check that each channel is connected correctly to the physical device (the appropriate channel of the NI 9234 module) by right clicking on the channel indicator (for instance "Voltage_0") and then selecting "Change physical channel". This will open a window as in figure 3, which displays the supported physical channels (e.g., ai0 to ai3) and the associated device (Dev1, Dev2, etc. or cDAQ1Mod1, cDAQ1Mod3, etc.) at the top, as well as, at the bottom, the current physical channel associated with the selected channel, if any. If a NI 9234 analogue input module is not connected to the PC, the list of supported physical channels will be blank or contain only other types of modules. Then a NI 9234 analogue input module first needs to be connected before one can proceed. With the NI 9234 connected and the channels listed in the supported physical channels list, if there is no current physical channel associated with the channel in question, simply select one from the list and click "OK". If the channel is correctly indicated and nothing needs to be changed, "Cancel" can be selected.

  Back on the main configuration window of the DAQ Assistant (figure 2): it is not necessary to set the "Timing settings" at the bottom ("Acquisition Mode", "Samples to Read" and "Rate"). These parameters are set by the program. Once everything in the DAQ assistant configuration window has been set up correctly, click the OK button at the bottom right to close this window and to configure the DAQ assistant (or "Cancel" if nothing has been changed).

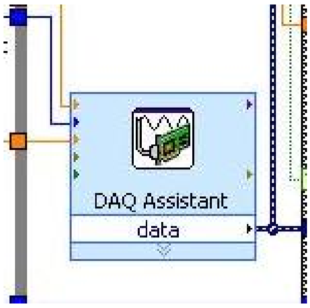

Figure 1: DAQ Assistant icon on block diagram

- The measurement transducers should be connected to the various channels.

3 Starting and stopping the program

To start the program, open the front panel (see section 2) and click on the start button, , just below the "Edit" and "View" pull down menus at the top left of the window (see figure 4). To stop the program before completed execution, click on the stop button, , just below the "Project" pull down menu at the top left of the window (see figure 4 or 5).

Once the program has started, the start button changes to look like this: , while the grid over the window disappears and the window then looks like that shown in figure 5. This appearance is always to be seen as an indicator that the program is actually running.

Once the program has been started, the following three main actions should take place, the first and last executed by the user and number 2 automatically by the program once started by the user:

1. Setting up the measurement
2. Doing the measurement, i.e., performing the data acquisition
3. Post measurement data observation and storage.

These actions are described in more detail in the next three sections.

4 Setting up the measurement

With the program running, the user can set up some measurement parameters and observe, to some extent, their effect, before commencing with the actual measurement. A parameter that the user can adjust is mostly indicated in a white background block with a pair of increment arrows on the left. The desired value can be typed in this block, or the value displayed may be changed by clicking on the increment arrows. If the program is running, it will calculate the resulting parameters indicated in the blocks without the selector arrows (with a light grey background). All the parameters that need to be set before commencing with the measurement are included in the square in figure 5. They are:

- **Discrete sampling rate factor n**: The NI 9234 Operating Instructions and Specifications (linked to document on DSG website), page 16, indicates that the sampling rate of the unit is $f_s = f_M/256/n, f_M = 13.1072$ MHz. The discrete sampling rate factor is the integer $n, 1 \leq n \leq 31$, in this formula. When $n = 1$, the highest possible sampling rate of 51.2 kHz is selected, while with $n = 31$, the lowest possible sampling rate of 1651.61 Hz is selected. With the program running the resulting sampling rate selected is displayed under "Meas: fs (Hz)". The unit automatically adjusts the anti-aliasing filter according to the selected sampling rate.

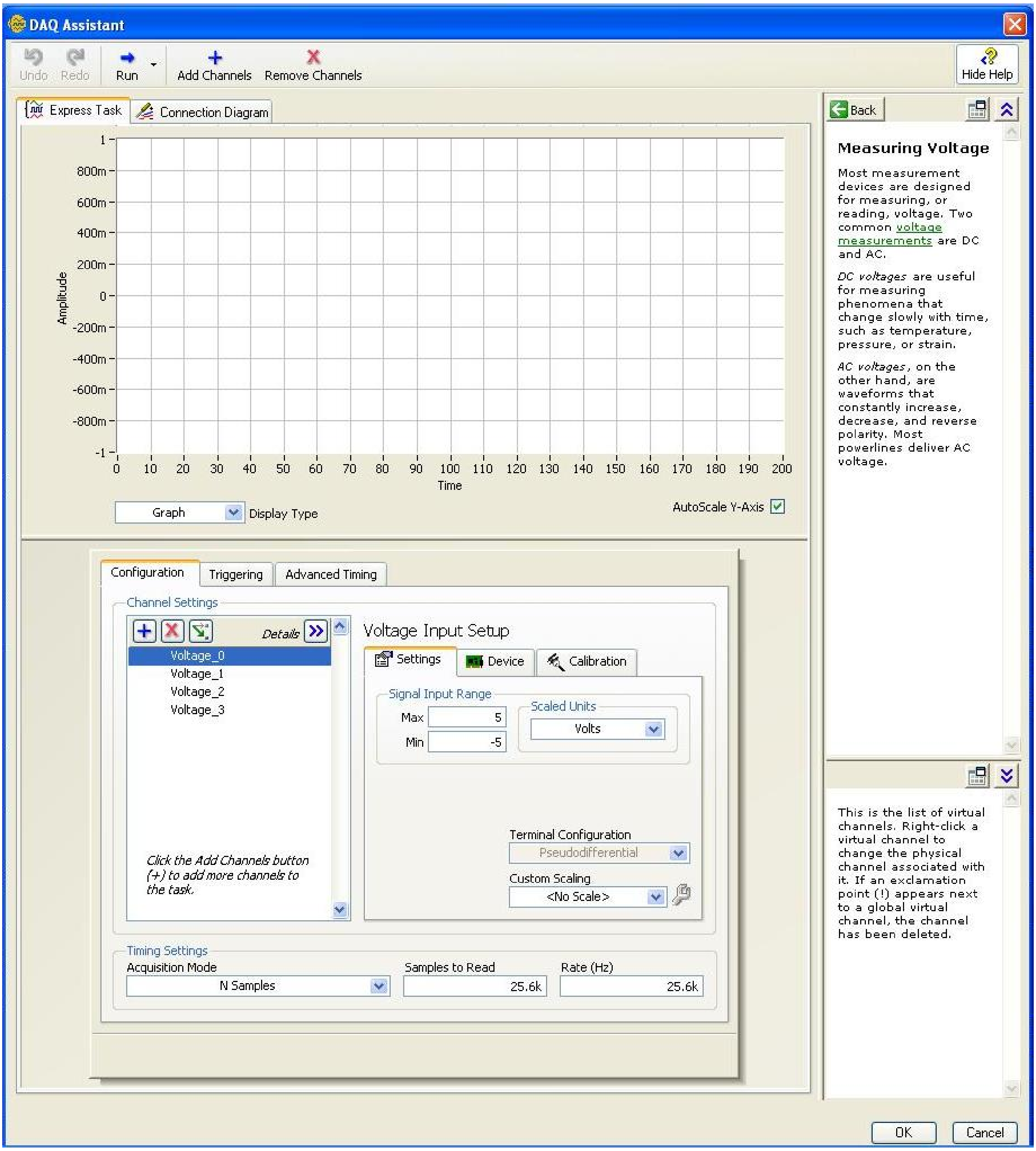

Figure 2: DAQ Assistant configuration window

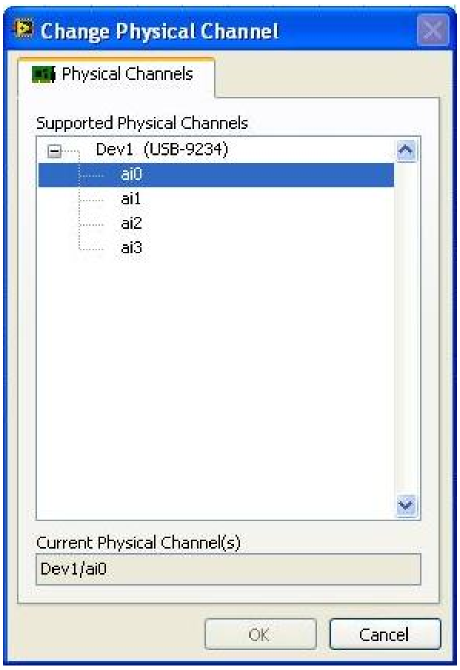

Figure 3: "Change physical channel" window for a selected channel, indicated to be connected to physical channel ai0 on device Dev1

- If a lower sampling rate is required, the program decimates the measured signals by a factor 2^k, k an integer, $0 \leq k \leq 6$. Before decimation, appropriate digital low pass filtering is applied to avoid aliasing. The exponent k is set in the field **Divisor below 1.65kHz: exp of 2**. Decimation introduces inaccuracies at low frequencies.
- The number of lines 2^l, $8 \leq l \leq 14$, used in the FFT calculations can be set, by setting the integer l in the field **exp of 2**, just above "No lines in FFT". The running program will echo the number of lines calculated.
- **Number** (of) **averages (max 100)** is the number of averages to be taken in the power and cross spectrum calculation, with normal linear averaging. The maximum is 100.
- **% overlap (max 50)** determines the percentage of time window overlap during the averaging process. The program uses this and the number of lines in the FFT to then calculate and display the number of lines advance associated with each member time window in the average.
- **Window type**: The window to be used to prevent smearing of the FFT is selected from a pull down menu. The last option, "square", means that no window is used. The "flat top" window is most appropriate to get an accurate reading on sinusoidal amplitude, while the "Hanning" window is usually used for analysis of predominantly random signals and results in the most accurate determination of the frequencies of sinusoidal content.

5 Doing the measurement

Once the measurement parameters have been selected, the measurement can be started by clicking the "Start measurement" button, in the right bottom corner of the rectangle in figure 5.

While the measurement is being made, the "Measurement" light, just to the right of the measurement setup rectangle (see figure 6) will be lighted. If decimation had been selected (by selecting a value larger than 0 in the "Divisor below 1.65kHz: exp of 2"-field), the "Decimation" light, just below, will also be shining.

The moment the required number of samples had been read, the "Measurement" and "Decimation" lights will go out and the "Graphs" light will come on, indicating that observation of graphs and saving of output files are now possible. Also, at this stage, the time increment between measured samples and the sampling frequency, after decimation if used, are displayed in the "delta t (s)" and "fs (Hz)" fields, respectively, to the right of and above the "Measurement" light.

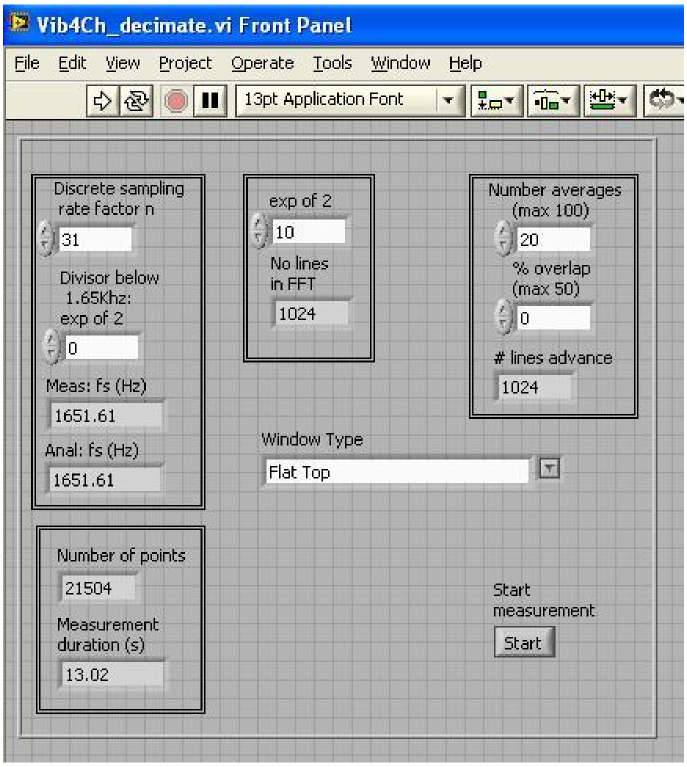

Figure 4: Top left part of Vib4Ch_decimate front panel, program not running

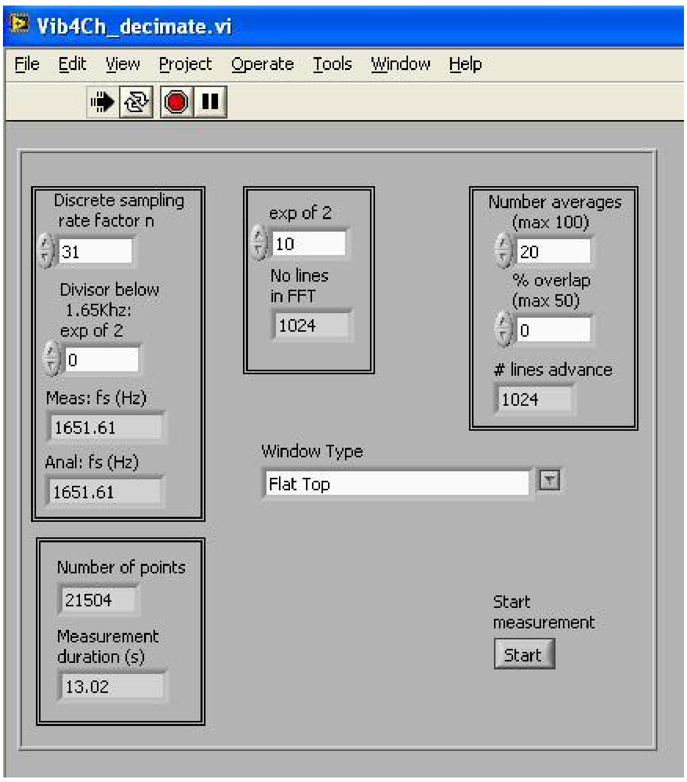

Figure 5: Top left part of Vib4Ch_decimate front panel, program running

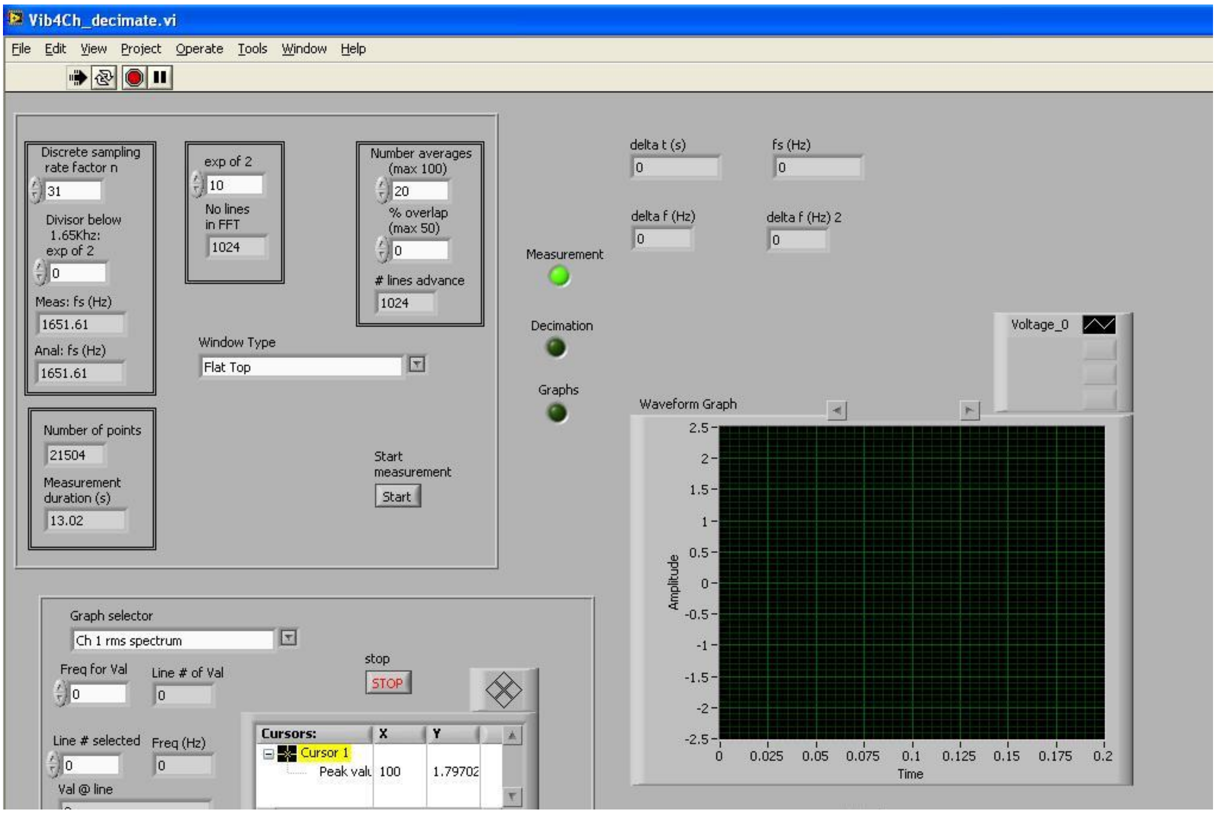

Figure 6: Top part of Vib4Ch_decimate front panel, program running and busy with data acquisition

The program also determines the frequency resolution value of the resulting spectra, both by dividing the sampling frequency by the number of lines in the FFT and as an output from the standard subroutine used to calculate the power spectra; both these values (which should be the same) are then displayed in the “delta f (Hz)” and “delta f (Hz)2” fields. All of this is illustrated in figure 7.

After the measurement has been completed, the decimated, if selected, or otherwise full time histories of all four channels are displayed in different colours as labelled at the top right, on the “Waveform Graph” just below the above mentioned output fields and to the right of the “Graphs” light (see figure 7). This graph has a fixed time width, unrelated to the spectrum calculation, and can be scrolled forward and backward in time, for the whole measurement duration as displayed in the field in the rectangle in figure 5, with the scroll bar just above the graph. Note that the fixed width of the graph cannot be changed while the program is running. Once the program is stopped, however, it can be changed by right clicking on the graph, then selecting “properties” from the menu that appears after a while, then selecting the “Scales” tab and then adjusting the “Minimum” and “Maximum” values. As the scroll bar is available, these two values only fix the time increment between the left and right hand side borders of the graph and not the minimum and maximum time values in an absolute sense.

The program also shows, after measurement completion, the time history of the last FFT time window of channel 1, after the selected anti-smearing window has been applied, in “Waveform Graph 2”, below the full time histories of all four channels (see figure 7). The time scale of this graph is not an absolute scale.

6 Post measurement data observation and storage

Except for viewing the full time histories of all four channels as described above, the interaction of the user with the still running program after the measurement has been completed is contained in the bottom left rectangle on the front panel, as shown in figure 8.

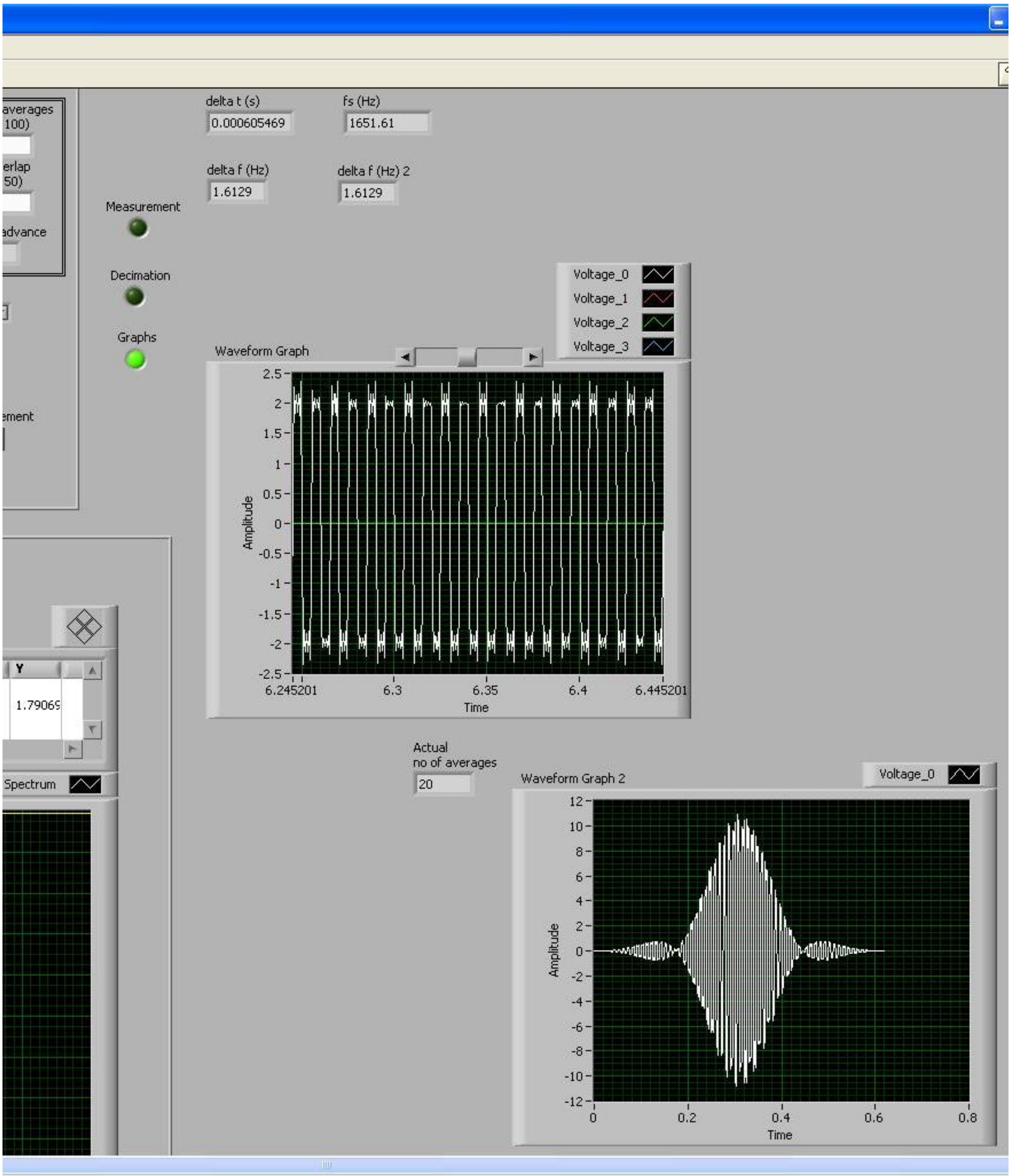

Figure 7: Top right part of Vib4Ch_decimate front panel, program running, after completion of data acquisition. In this case Channels 1 and 2 were measuring the same 100 Hz 4 Volt peak-to-peak value square wave, while channels 3 and 4 were not connected to anything. The ripples in the 2 V and -2 V regions of the time graph is caused by the anti-aliasing filter.

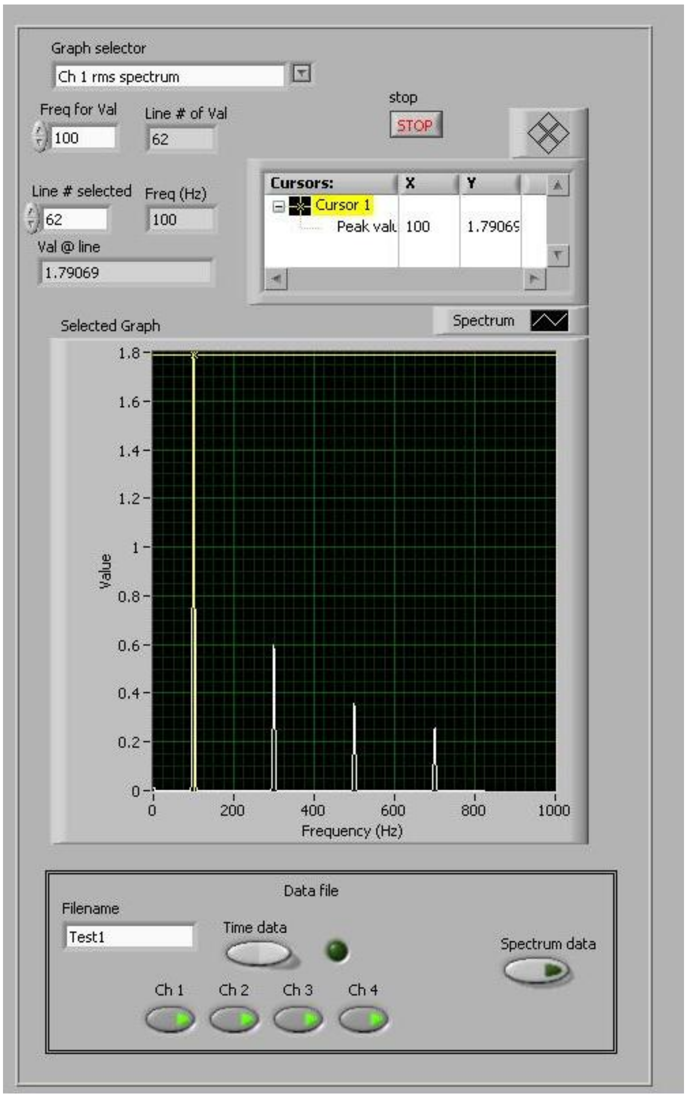

Figure 8: Bottom left part of Vib4Ch_decimate front panel, program running and allowing observation of graphs and ready for file storage

6.1 Displaying averaged frequency domain data

The "Graph selector" pull down menu allows the user to display on the "Selected Graph" below one of a number of averaged frequency domain results. The rms spectra are merely the square root of the single sided power spectra. The units of the vertical axes of these graphs are Volt rms. The frequency response functions available are those of channel 2 with channel 1 as reference, and channel 4 with channel 3 as reference. These can, however, easily be changed by changing the wiring in the block diagram (i.e., changing the program; see section 7). The phase graphs are displayed in degrees. For power spectral density graphs, see note in section 6.2.2 below.

Once a graph is displayed on 'Selected Graph", the yellow vertical cursor can be dragged with the left mouse button to a specific frequency. The horizontal cursor indicates the vertical axis value of the graph at the vertical cursor location and both coordinates are displayed in the cursor box above the graph. The frequency location of the vertical cursor can also be adjusted by clicking on the left or right diamonds in the four-diamond pattern above the cursor box. The upper and lower diamonds are de-activated as the horizontal cursor is set to follow the vertical cursor as described above.

As the cursor adjustment with the diamonds are somewhat sensitive, a FFT line number calculator is provided just below the "Graph selector". The user can enter a frequency value on the left ("Freq for Val", in Hz) and the calculator will then return the nearest line number on the right ("Line # of Val"). The user may then enter the line number in the box below: "Line # selected" and the program will then supply the actual frequency of that line in the box to the right, "Freq (Hz)", as well as the graph value at that line/frequency in the box below, "Val @ line". The pair of increment arrows on "Line # selected" can be used to explore the graph values at nearby lines (for instance to ensure that a peak value has been identified correctly).

6.2 Writing data to a file

The user may choose to write data to comma separated files. These files may be imported into a spreadsheet program like EXCEL or may be read by a MATLAB or OCTAVE program. The file output is controlled by the "Data file" fields in a rectangular box below the "Selected Graph" (see figure 8).

Time domain data and frequency domain data are written to two separate files. The user can enter a filename in the "Filename" box. This filename is then appended with "_time.csv" in the case of time domain data, or "_spec.csv" in the case of frequency domain data. The output data files are stored in the same folder (directory) as where the Vib4Ch_decimate.vi file is stored.

6.2.1 Time domain data

The un-decimated time histories are written to the file; hence a very large file can result if the measurement setup is such that a large number of samples are measured. By default the time histories of all four channels are written to the file, but unused or unimportant channels can be deselected before the file is written by clicking on the channel toggle buttons right at the bottom of the "Data file" field (a light that is on indicates that the channel will be written to the file). The first column in the file will be the time points, starting from time 0, and the next column(s) are the selected channel voltage values (the selected channels in sequence 1,2,3,4) at the corresponding times in column 1. The file is written only when the "Time data" switch is pressed (clicked) and the file with the currently set filename, if it exists, is overwritten every time this button is pressed with the program running. While the switch is pressed the light to the right of the switch comes on to confirm that the data is written. If no channel is selected to be written to the file, the file will not be written and the light will not come on while the "Time data" switch is pressed.

A program that can be used (after logical editing) in both MATLAB and OCTAVE to open the comma separated file and plot the data (`plotLABVIEWtime.m`) is supplied with the Vib4Ch_decimate program.

6.2.2 Frequency domain data

Since the frequency domain data files are relatively small, no facility to deselect information to be written to the file is provided. All the data available for plotting on the "Selected graph" (as indicated in the pull down menu) are written to the file the moment the "Spectrum data" button is pressed. The light on the button will come on while the button is being pressed indicating that the data is written to the file. The file with the currently set filename, if it exists, is overwritten every time this button is pressed with the program running. The data is written to the file in the following manner: the first column is the frequency values in Hz, starting at 0 Hz. The second to eleventh columns are the values of the 10 items in the "Graph selector" pull down menu at the corresponding frequencies in column 1, in sequence, i.e., channels 1, 2, 3 and 4 rms spectra (in this sequence, columns 2 to 5), frequency response function magnitude, phase and coherence of channel 2 with channel 1 as reference (channels 6 to 8) and frequency response function magnitude, phase and coherence of channel 4 with channel 3 as reference (channels 9 to 11) (phase angles in degrees).

A program that can be used (after logical editing) in both MATLAB and OCTAVE to open the comma separated file and plot the data (`plotLABVIEWspec.m`) is supplied with the Vib4Ch_decimate program.

If the user is interested in power spectral density graphs, rather than power spectra (or rms spectra), these can easily be calculated in MATLAB or OCTAVE, after having run the `plotLABVIEWspec.m` code, by first squaring the appropriate rms spectrum column (to obtain a power spectrum) and then dividing this by the "delta f"-value of the analysis, which is displayed on the Vib4Ch_decimate front panel after data acquisition (see figure 7). The resulting column is the measured power spectral density of the corresponding channel.

6.3 Normal stopping of the program

Normally program execution is stopped once the user is satisfied that the measured and frequency analysed data has been displayed and stored to files, if required. This is done by clicking on the red "STOP" button just above the cursor block. Once the program is stopped, the "Graph selector", frequency line calculator and file output functions are no longer available.

7 Doing things not currently provided for in the program

The user can easily modify his/her copy of the program on his/her own machine, to do various things not currently provided for in the program. For this some knowledge of LABVIEW programming is advisable. The program is changed by changing the block diagram, accessible by pressing Ctrl-E on an active (but not running) block diagram window (see section 2). The author is willing to lend some help in changing the program to meet specific needs (X3309, nico.theron@up.ac.za). The author is also open to suggestions and offered assistance to improve the current program.