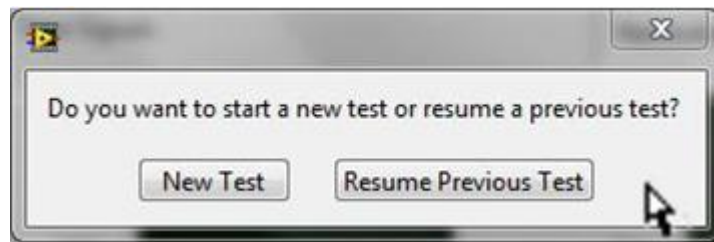


User Manual for Labview On-Board Sound Intensity Testing

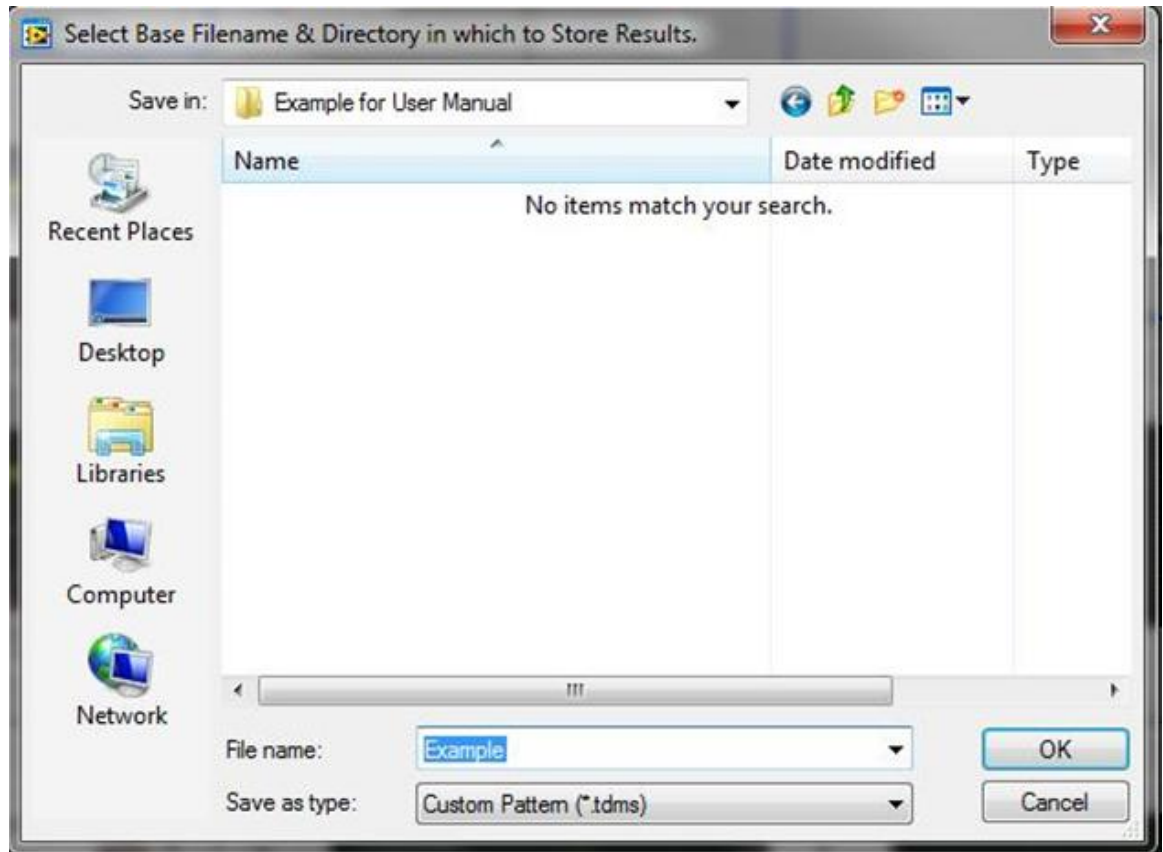
The following manual provides a detailed description of the National Instrument's Labview program as it has been developed for On-Board Sound Intensity (OBSI) testing. To demonstrate the various features of the program, a simple bench test was used as an example. While road testing was conducted during the development of the program, none of those results are shown in this example. Note, during the road testing, it was determined that plugging the laptop computer into the vehicle's power source caused grounding issues to show up in the results. Therefore, at no time during road testing should the laptop be plugged into the vehicle; either test only when the laptop is at full power or include a secondary power supply in the vehicle during testing.

(1) *Open Labview Program* – Open the program. When Labview opens, the **Test Procedure** window will be displayed, and a pop-up box will appear.

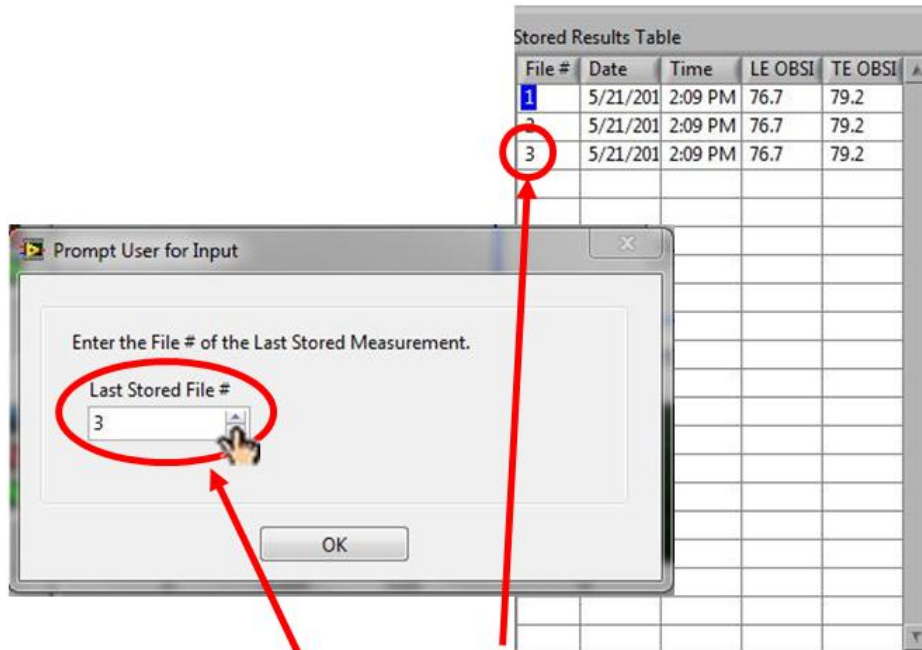
- (a) The pop-up box prompts the user by asking, “Do you want to start a new test or resume a previous test?” This will allow the user to resume the numerical sequence of data files from a previous test.



- i) If the user chooses “New Test,” then the “No. of Saved Files” box on the **Test Procedure** window goes to “0,” and the “Stored Results Table” automatically clears. Another pop-up box appears, prompting the user to select a base filename for and location to store the data for the following test. Further information can be found under Step (5) *Select Storage Location for All Measurements*.

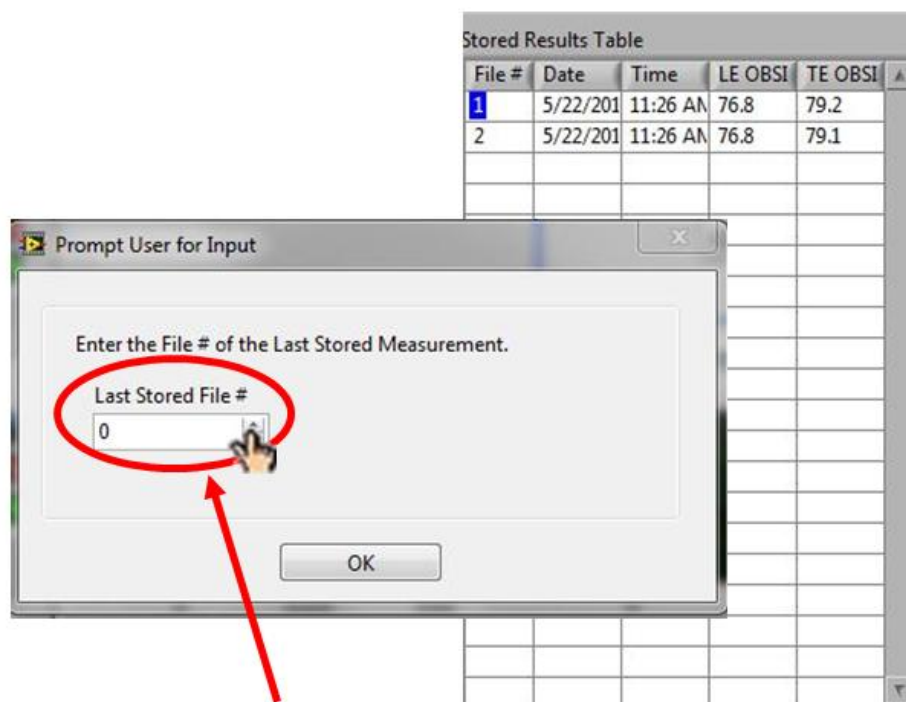


- ii) If the user wants to continue numbering where the previous test session left off, then “Resume Previous Test” should be selected. Another pop-up screen appears, prompting the user to “Enter the File # of the Last Stored Measurement.” The user should enter the last number shown in the “Stored Results Table” on the display screen and hit “OK.” On the **Test Procedure** window, the value that appears in the “No. of Saved Files” should match the user input, and the “Stored Results Table” should continue to display previously stored data.



The user input should match the last test run #.

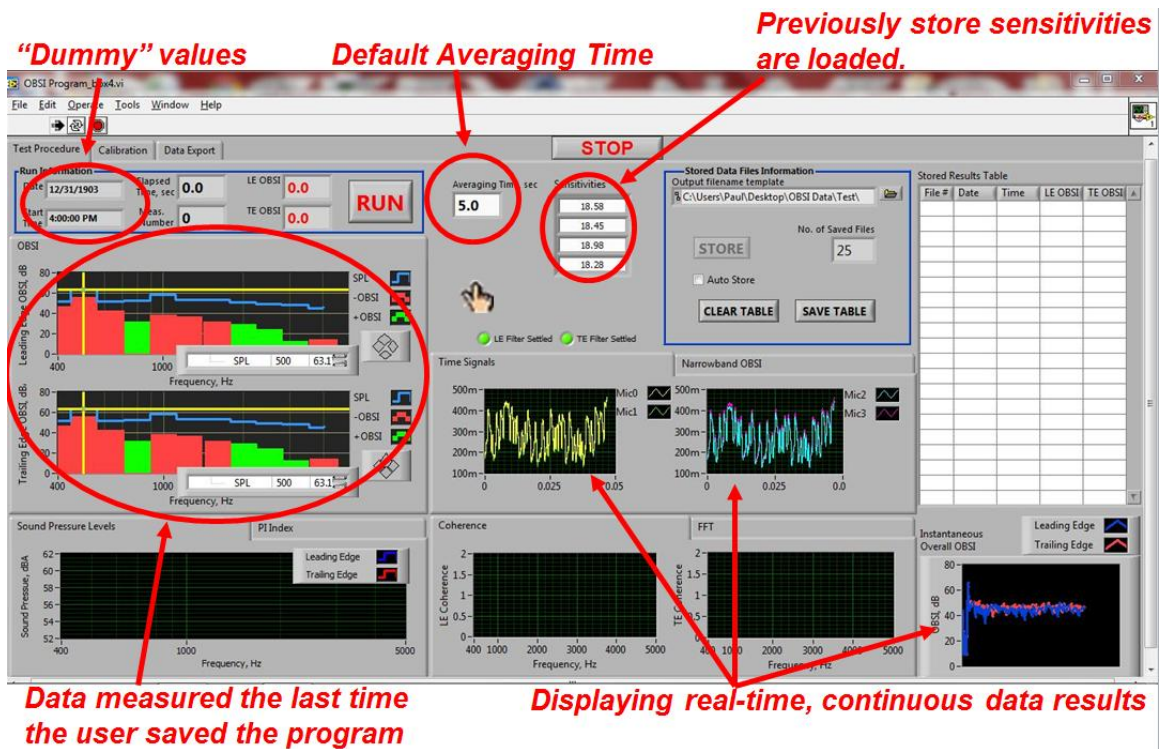
- iii) If the user wants to keep the previous data displayed in the “Stored Results Table” but start a new number sequence for this test set, then after selecting “Resume Previous Test,” the user should enter “0” for the “Last Stored File #” and press “OK.”



To restart a new number sequence, enter 0.



- i) Press “Stop,” and the program will close automatically. Check and correct the hardware connections and reopen the file.
 - ii) Pressing “Continue” would keep the program open, but the same error message would repeatedly pop-up until the user finally selects “Stop.” As with most testing systems, if the interface connection is broken, the best practice approach for Labview is to close the program and check all connections before reopening the program.
- (c) Once activation has begun, the “Time Signals” and “Instantaneous OBSI” plots start running automatically. Data displayed in these figures run continuously while the program is open. Also notice that the “Sensitivities” stored from the last calibration cycle are loaded, as well as a *dummy* “Date” and “Start Time.” “Elapsed Time, sec,” “Meas. Number,” “LE OBSI,” and “TE OBSI” all read “0.” On the left-hand side of the front panel screen, below the “Run Information” box, the “OBSI” plots also contain data. The plots shown represent the last data measured when the user saved the program file.



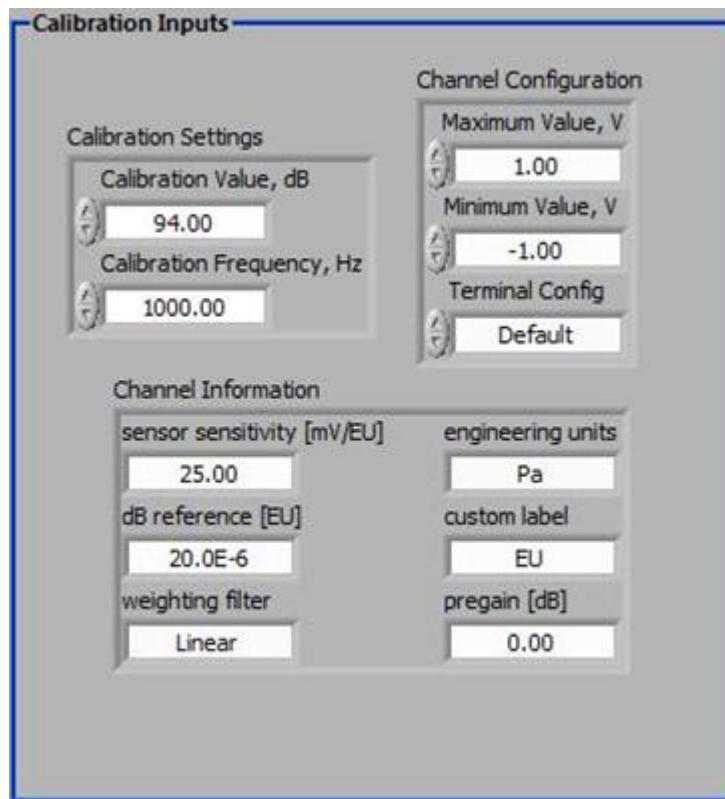
(2) *Calibrate the Microphones* – select the **Calibration** tab at the top of the screen to open the window. By design, the program operates only the displayed window that is designated by the selected tab. Therefore, once the user selects the **Calibration** tab, only the calibration algorithms will be operable.

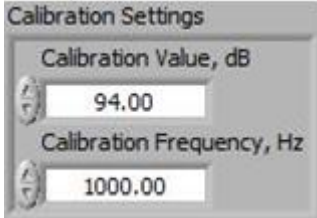
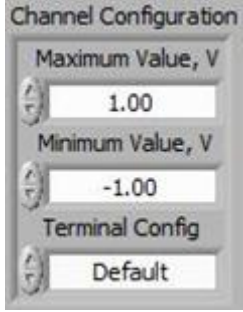
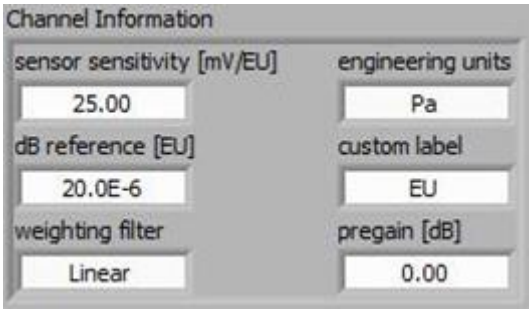


(a) The **Calibration** window is designated into two boxes of information: “Calibration Inputs” and “Calibration Outputs.” The inputs are values that can be modified by the user, if needed, while the outputs summarize the results of each calibration iteration.



- i) “Calibration Inputs” – all information shown in the figure below (and summarized in the table below) reflects the programmed default information and is standard for most OBSI testing. If any value shown below is not what appears on the screen and/or is not valid for the user’s system hardware, the user can click in any white box or, where permitted, select the up and down arrows to adjust to the correct input parameters.



Icon	Name	Value	Description
	Calibration Value, dB	94.00	Microphones are calibrated to be 94.0 dB at 1000 Hz
	Calibration Frequency, Hz	1000.00	
	Maximum Value, V	1.00	Specifies the input limits and terminal configuration
	Minimum Value, V	-1.00	
	Terminal Config	Default	
	Sensor sensitivity [mV/EU]	25.00	Nominal calibration input information
	Engineering units	Pa	
	dB reference [EU]	20.0E-6	
	Custom label	EU	
	Weighting filter	Linear	
	Pregain [dB]	0.00	

- ii) “Calibration Outputs” – prior to calibrating the microphones, the information that automatically loads when the program is activated summarizes the results from the last time the microphones were calibrated. The program is designed to store the calibration sensitivities calculated each time a microphone channel is recalibrated. These stored sensitivities are automatically used for all testing until the channel is recalibrated, and a new sensitivity is recorded. Therefore, the values shown in the figure reflect the last stored calibration information. The table below summarizes the output “Calibration Channel Information” previously calculated. The

Calibration Outputs

Cal Sensor Sensitivity, mV/Pa

Cal Sensor Sensitivity Coefficient

Cal Sensor Sensitivity Adjustment, dB

Magnitude, dB

Calibration Channel Information

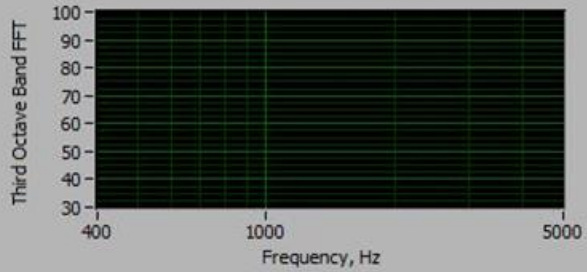
sensor sensitivity [mV/EU] engineering units

dB reference [EU] custom label

weighting filter pregain [dB]

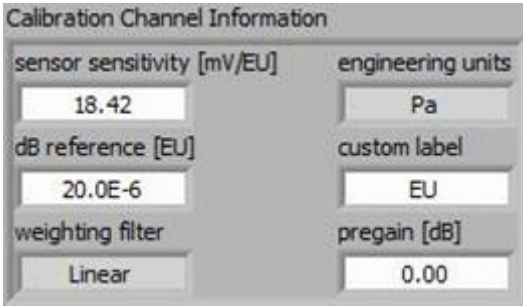
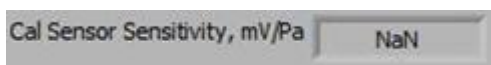

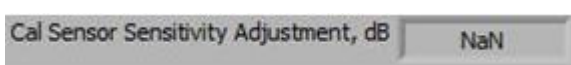
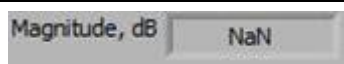
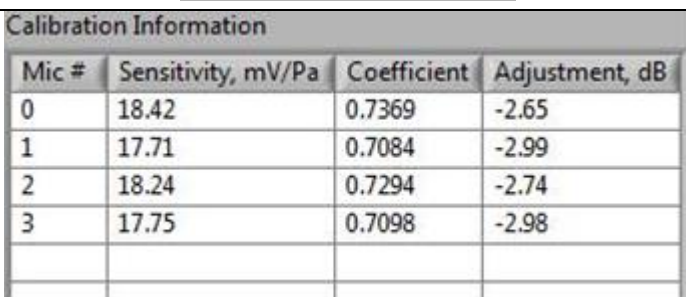
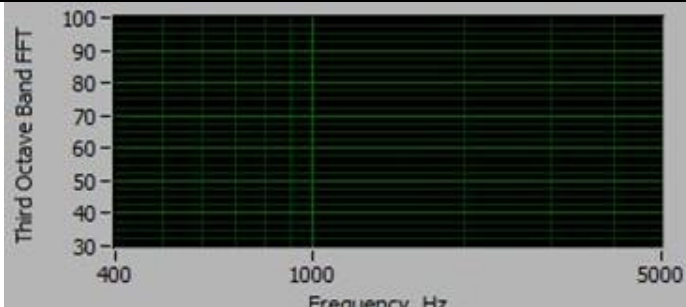
Calibration Information

Mic #	Sensitivity, mV/Pa	Coefficient	Adjustment, dB
0	18.42	0.7369	-2.65
1	17.71	0.7084	-2.99
2	18.24	0.7294	-2.74
3	17.75	0.7098	-2.98



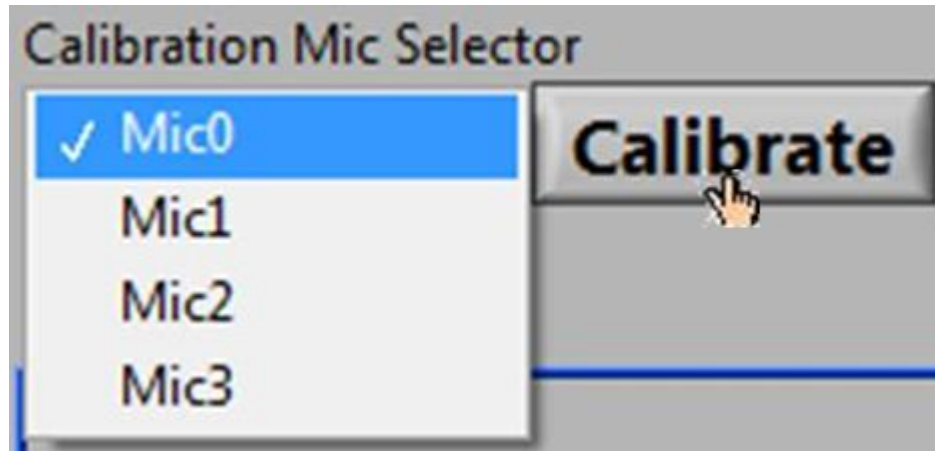
Filter Settled-Calculation

Filter Settled-Cal Check

Icon	Name	Value	Description
	Sensor sensitivity [mV/EU]	18.42	Calculated output information from last calibration sequence
	Engineering units	Pa	
	dB reference [EU]	20.0E-6	
	Custom label	EU	
	Weighting filter	Linear	
	Pregain [dB]	0.00	
	Cal Sensor Sensitivity, mV/Pa	NaN	Calculated values in the current calibration sequence. Until the selected channel is calibrated, "NaN" will appear
	Cal Sensor Sensitivity Coefficient	NaN	
	Cal Sensor Sensitivity Adjustment, dB	NaN	
	Magnitude, dB	NaN	
	Calibration Information	Sensitivity info for each channel	Existing stored information. Each time a channel is recalibrated, the displayed info updates
	Third Octave Band FFT	FFT plot	Using the calculated sensitivity

(b) From the drop down box located above the "Calibration Inputs," select the microphone to be calibrated. Place the calibration device on the microphone plugged into the channel that corresponds to the selected microphone, run the 94.0 dB caltone into the microphone and hit the "Calibrate" button (or hit <F1> on the keyboard). By design, the calibration algorithm is programmed to

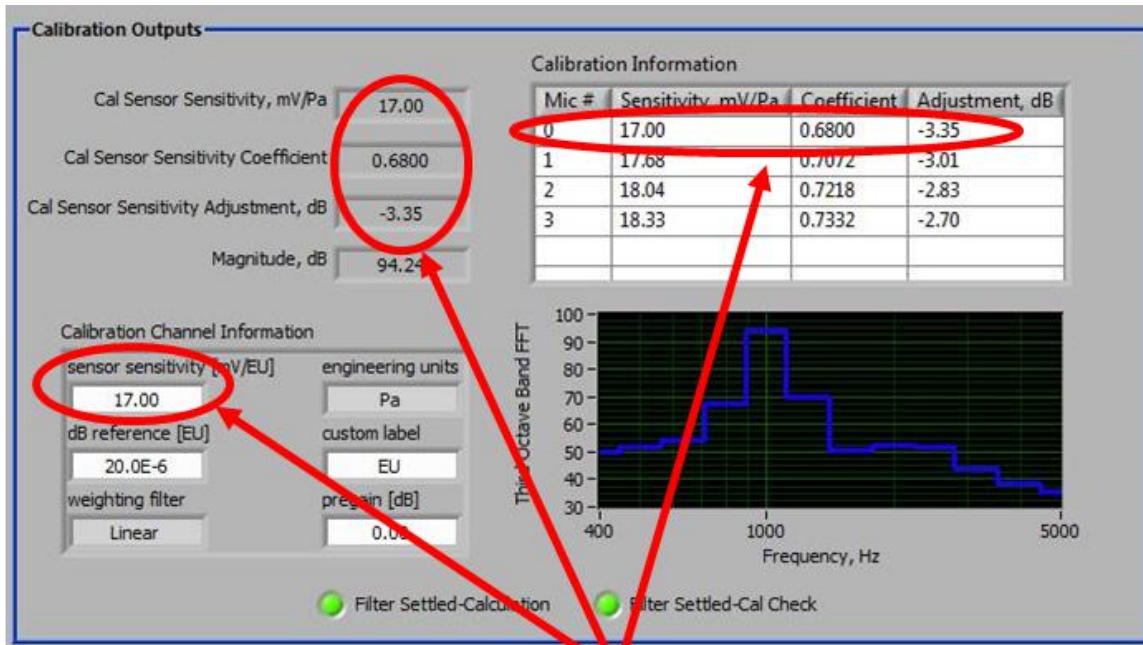
take 5 seconds each time the “Calibrate” button (or <F1> on the keyboard) is pressed.



- (c) During the 5-second calibration calculation, there is a time lapse bar to indicate how much time has lapsed in the 5-second period.

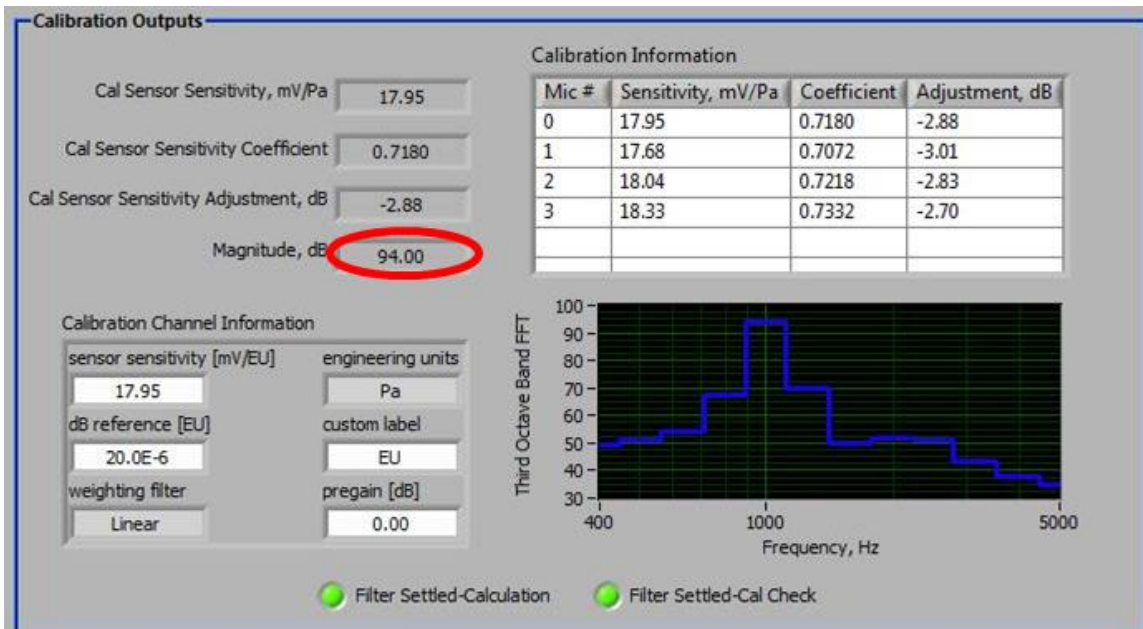


- (d) After the 5-second algorithm is completed, the display screen automatically updates to reflect the results. Simultaneously, the program is designed to automatically store the measured sensitivity. The new calculated sensitivity information will be stored until this channel is recalibrated. The measured sensitivity information for the selected microphone is displayed in the “Calibration Channel Information” box, replaces the previously measured sensitivity information in the “Calibration Information” summary table, and replaces the output boxes previously labeled as “NaN.” Additionally, the “Magnitude, dB” box and the plot of the third-octave band FFT update. These results reflect the FFT plot and magnitude information at 1000 Hz calculated using the newly-measured sensitivity.



The new calculated sensitivity information should be consistent in all 3 locations

- (e) Per proper calibration procedure, each channel should be calibrated several times until the new sensitivity is repeatable to the nearest hundredth and/or until the measured “Magnitude, dB” at 1000 Hz is equal to $94.0 \text{ dB} \pm 0.02 \text{ dB}$ (usually it takes 2 to 4 repetitions to achieve this precision).



- (f) Repeat (a) through (d) for the remaining microphones.

(3) *Check Sensitivities* – back in the **Test Procedure** window, which the user can access by clicking on the **Test Procedure** tab at the top of the screen, a box labeled “Sensitivities” is displayed in the center of the screen. The four values shown should match the calculated sensitivities from the **Calibration** window.

The screenshot displays two windows from a software application. The top window, titled "Calibration Outputs", contains several input fields and a table. The table, "Calibration Information", lists four microphones with their respective sensitivities, coefficients, and adjustments. The bottom window, titled "Test Procedure", shows a "Run Information" section with a "RUN" button and a "Sensitivities" list. Red circles highlight the sensitivity values in both windows, and a red arrow points from the Calibration window's table to the Test Procedure window's list.

Mic #	Sensitivity, mV/Pa	Coefficient	Adjustment, dB
0	17.95	0.7180	-2.88
1	17.77	0.7109	-2.96
2	18.12	0.7249	-2.79
3	18.44	0.7376	-2.64

Test Procedure window Sensitivities list:

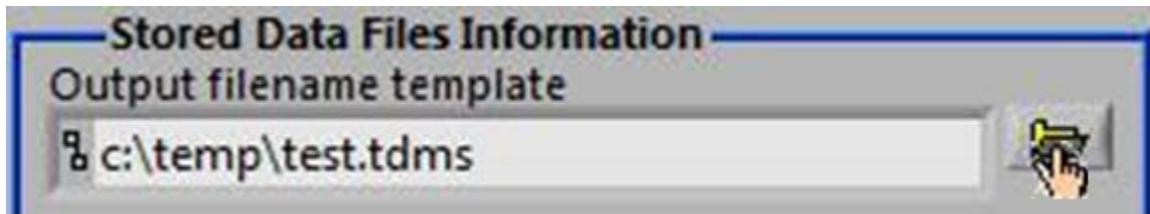
- 17.95
- 17.77
- 18.12
- 18.44

The sensitivities determined during calibration should be automatically updated in the Test Procedure tab

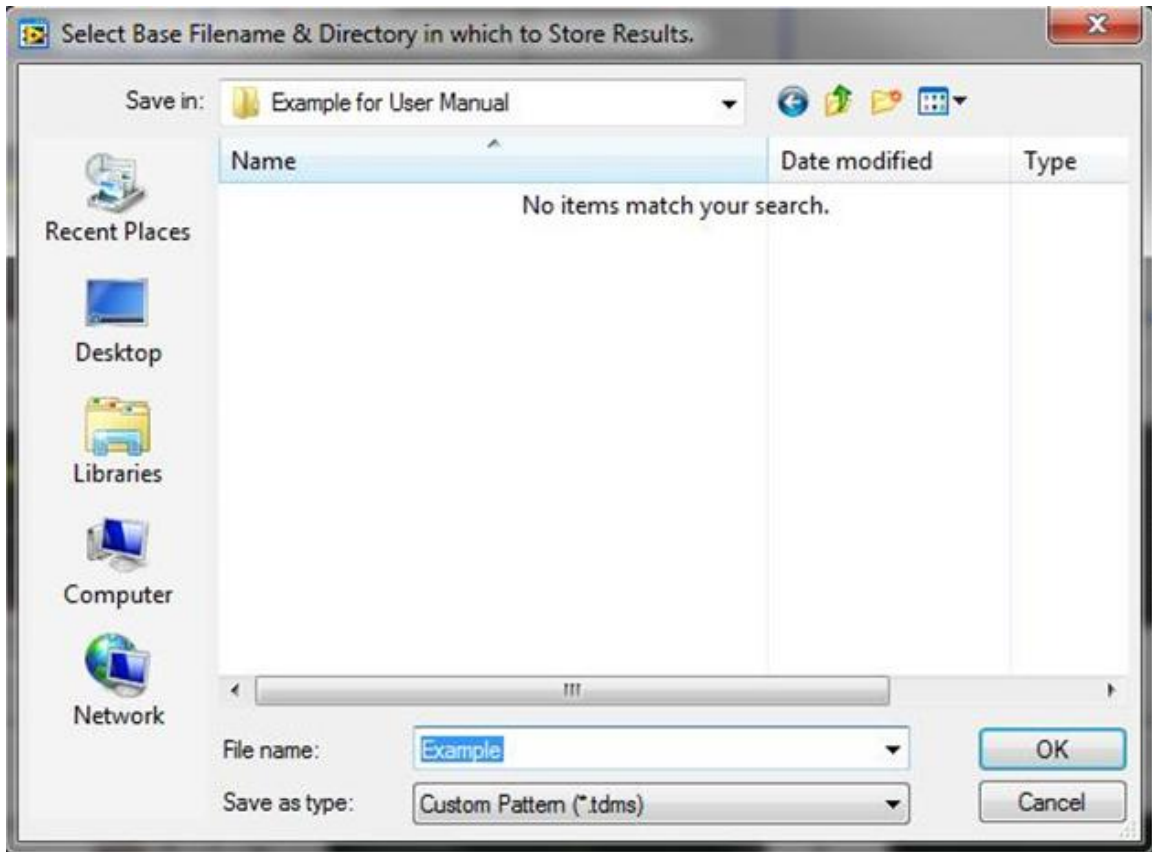
- (4) *Verify Averaging Time* – by default, the program is designed to run for five seconds. If the user requires a shorter or longer averaging time, however, then the acquisition time can be changed. The white box labeled “Averaging Time, sec” automatically reads, “5.0” upon program activation, but at anytime before a test run starts, the user can click the mouse cursor in the box and change the time.



- (5) *Select Storage Location for All Measurements* – by default, the program is designed to store all measured data files in the *temp* folder on the *c://* drive of the computer. The program also assumes a base filename for the files: “test.” This is shown in the blue “Stored Data Files Information” box. However, the user has the option to change the destination location and/or the base filename by selecting the open-folder icon to the right of the address line.



- (a) A “Save As” pop-up screen appears. Once the user selects the location where the data files are to be saved and the base filename for the data files, press “OK” to return to the **Test Procedure** window. All data should be stored as *.tdms files and so the “Save as type” drop-down list should not be altered. The new location and base filename is now displayed in the address line of the “Stored Data Files Information” box.



- i)* When the user changes the base filename and/or location of the saved files, the “Stored Results Table” will automatically be cleared.
 - ii)* If the user wants to keep all data displayed in the “Stored Results Table” from a previous testing period, then the user should not change the name or location of the saved files. To export the new data and the older data shown in the “Stored Results Table” into the same file during post-processing, the *.tdms files can be copied into different directories later on.
- (b)* Each time a data file is stored during acquisition, the program is designed to read the address line, add a numerical counter that associates with the file numbers shown in the “Stored Results Table,” and insert a date and time stamp. For example, if the user selected the base filename of “Example,” as shown in the above figure, then the stored data files would be named: Example_#_[yyyymmdd]_[hhmmss].tdms. The program was designed this way to prevent the user from overwriting previously stored data.

(6) *Data Acquisition* – after the channels are calibrated and the test rig is in place, the user is ready to begin testing. Once the vehicle is up to 60 mph, the following steps detail the acquisition procedure for OBSI testing.

(a) Press “RUN” to start the 5-second data acquisition (or press <F5> on the keyboard).



i) After acquisition starts, the “RUN” button is grayed-out until the 5 seconds has concluded. Likewise the “Averaging Time, sec,” “Output filename template” address line, the “STORE” button, the “Auto Store” check box, the “CLEAR TABLE” button, and the “SAVE TABLE” button are also grayed-out during acquisition. So if the user accidentally presses a button on the keyboard associated with these buttons and/or presses one of these buttons on the screen, there will be no affect on the data acquisition. In Labview, when the buttons shown on the front panel are grayed-out, then the associating keyboard keys are also disabled. This prevents the user from disrupting the operation.



Grayed-out during 5-second acquisition

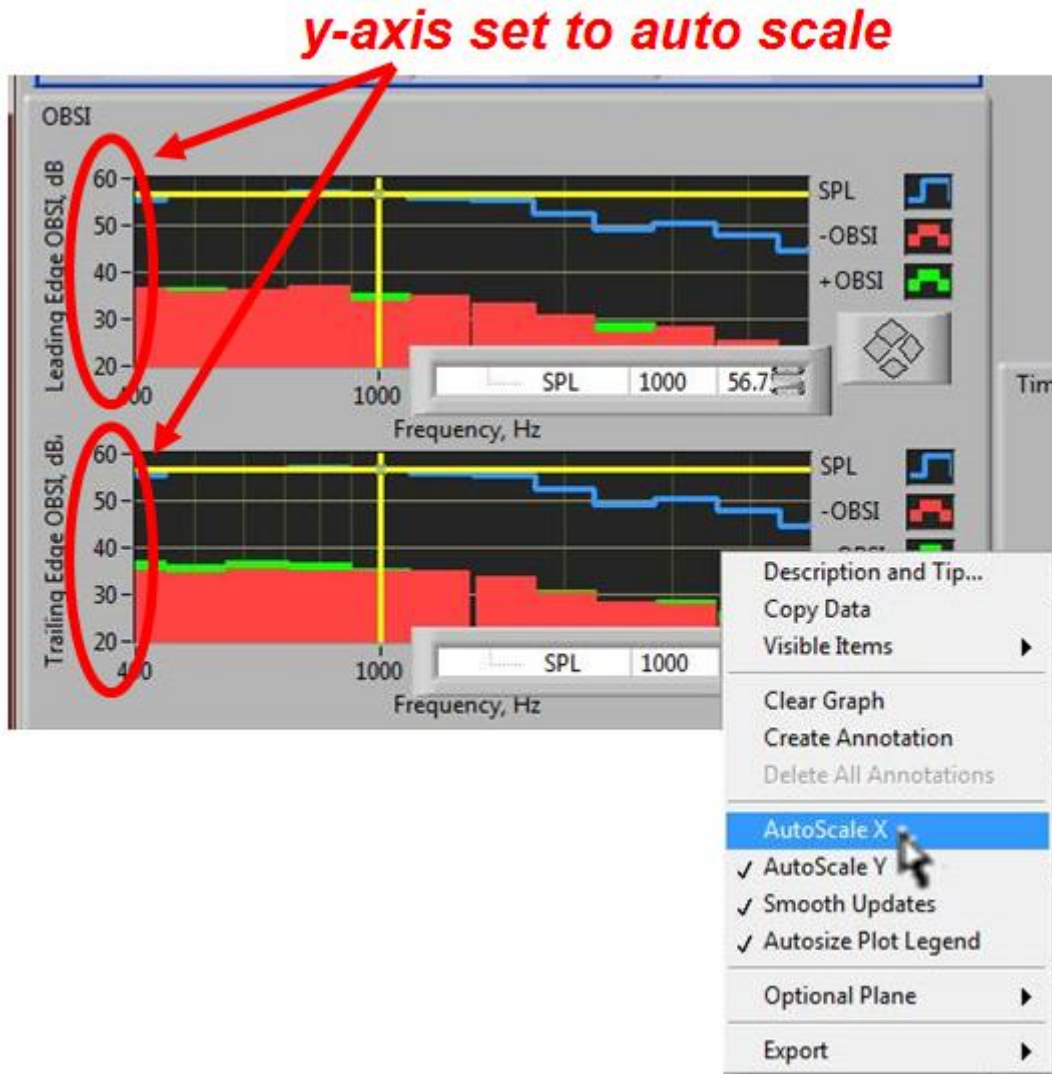
(b) During the 5-second acquisition, each plot displayed on the **Test Procedure** window shows the accumulating averages over the time period. At any time before, during, and after acquisition, the plot tabs can be selected so the user can monitor each type of data being acquired. Unlike the **Test Procedure**, **Calibration**, and **Data Export** tabs that control what type of analysis the user is conducting, all plots are constantly acquiring the average data regardless of the plot being displayed.

i) OBSI – the OBSI plots are A-weighted one-third octave band levels. The results for the leading edge probe, which consists of Mic0 and Mic1, are shown on top; the results for the trailing edge microphones (Mic2 and Mic3) are shown on the bottom. The blue lines on the plot represent the one-third octave band sound pressure levels (SPLs), which are also shown in a separate plot as well. Since sound intensity is directional, both positive (shown in green) and negative (shown in red) data are displayed. The orientation for standard OBSI testing protocol dictates that Mic0 on the leading edge probe and Mic2 on the trailing edge probe are positioned away from the tire while Mic1 and Mic3 on the leading and trailing edge probes, respectively, are positioned near the tire. The Labview program is designed for this orientation, and as such, all OBSI results are based off the data shown in green.

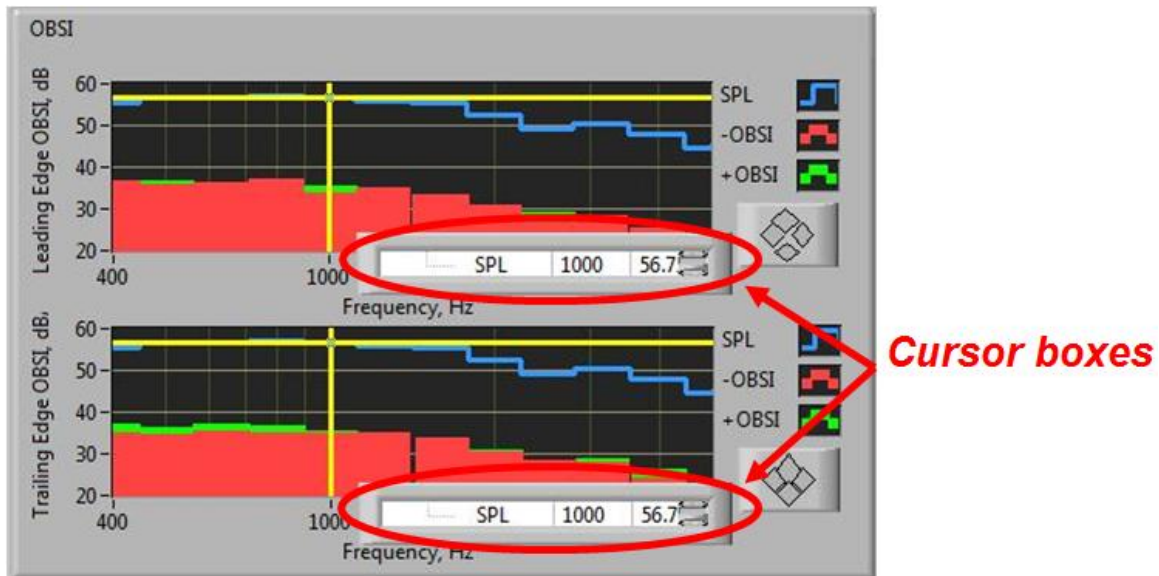


- For the OBSI, Sound Pressure Levels, FFT, and Narrowband OBSI plots shown on the **Test Procedure** front panel window, the y-axes are set to auto scale. However, the x-axes are fixed to show 400 to 5,000 Hz, which is the frequency range for all calculations in this program. If the user would like to auto scale the x-axis, as well, the user can position the mouse cursor over the figure to be changed and right-click on the mouse. Select the “AutoScale X” option, and Labview automatically adjusts the

domain to fit the data. Note, the “AutoScale Y” option is checked.



- The yellow cursor lines can be moved to the center frequency of each octave band to show the approximate magnitude of the plots. The boxes positioned in the lower right-hand corners of the plots show to which of the three functions the cursor is “snapped,” the center frequency to which the cursor is aligned, and the approximate magnitude at that selected frequency. For instance, both the leading and trailing edge OBSI plots have the cursor “snapped” to the SPL plot, and both have the cursors on the center frequency of 1,000 Hz; the average SPL magnitudes at the leading edge and trailing edge probes are 56.7 dBA.

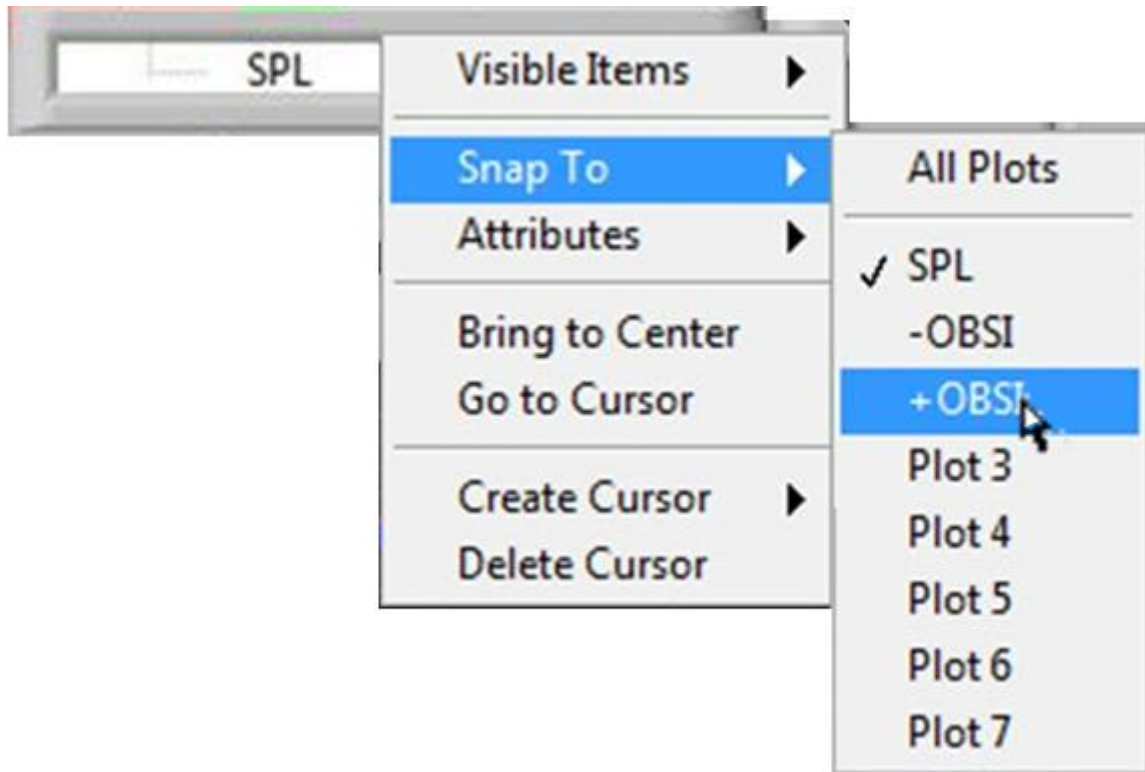


- To move the cursor to different center frequencies along the one-third octave band domain, simply put the mouse over the location where the vertical and horizontal cursor lines cross then press and hold the left button on the mouse and drag the mouse back and forth along the frequency domain and the cursor will snap to the next center frequency.

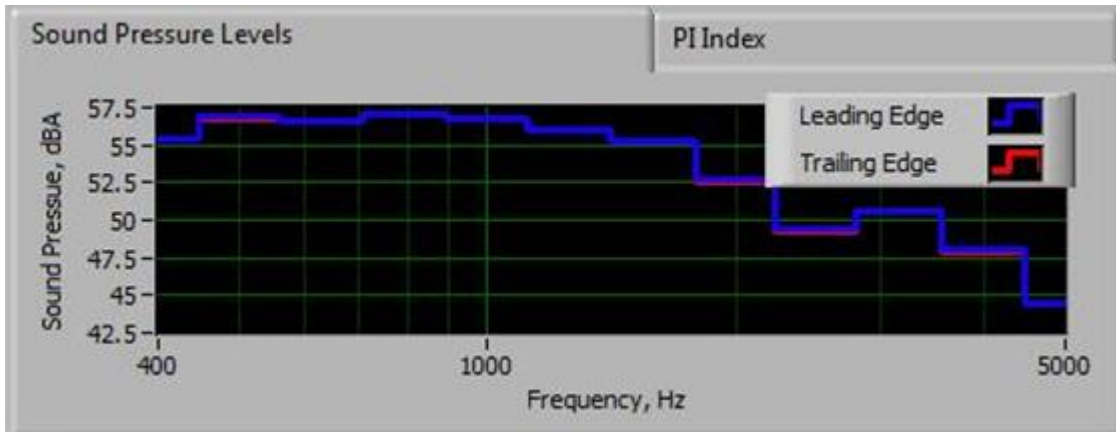


Put mouse on the cursor lines at the cross & drag left or right to obtain value at different frequencies

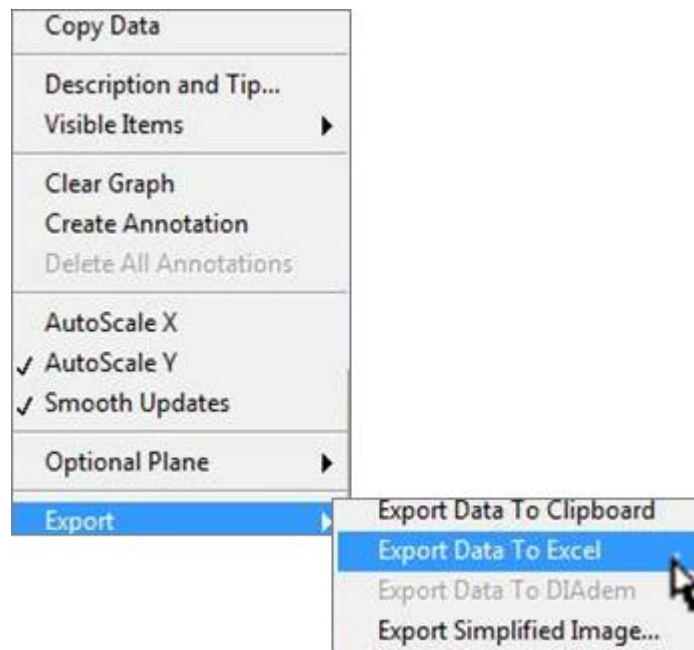
- If the user wants a change to which plot the cursor is “snapped,” simply position the mouse over the cursor box until the mouse turns into a hand and right click. Scroll down to “Snap To” and select which plot feature to which the cursor should be “snapped.”



- As the program is now, cursors have only been applied to the OBSI plots, but a cursor can be added to the other plots.
 - The OBSI data that is stored, displayed, and exported to Excel during post-processing is the OBSI data shown in green only. As discussed above, the standard configuration has Mic0 (on the leading edge probe) and Mic2 (on the trailing edge probe) positioned away from the tire; Mic1 (on the leading edge probe) and Mic3 (on the trailing edge probe) are positioned near the tire. If the orientation of the probes on the fixture is reversed, causing a directional change in the data results, then the program must be updated to accommodate these changes.
- ii)* Sound Pressure Levels – the sound pressure levels (SPLs) for both leading edge and trailing edge are displayed in one figure (leading edge is shown in blue; trailing edge is shown in red). Unlike OBSI results, SPLs are not directional. These spectra should match the SPL spectra shown in the OBSI plots.



- At any time during testing, the user can right-click on any plot, scroll down to “Export,” and quickly export the data contained in the plot to Excel by clicking on “Export Data To Excel.”



- Microsoft Excel automatically opens and copies the plot data into columns in a worksheet. In this example, the one-third octave band frequency domain and SPLs for the leading edge probe are copied into columns A and B, respectively. The frequency and SPLs for the trailing edge probe are copied into columns C and D, respectively.

Microsoft Excel - lvtemporary_110836.tmp

File Edit View Insert Format Tools Data Window Help

100% Arial 10

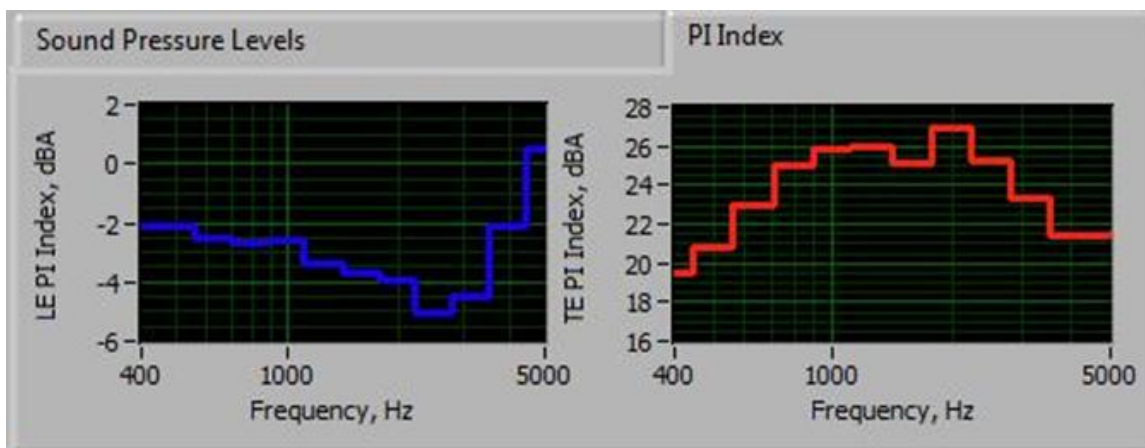
Reply with Changes... End Review...

Frequency, Hz - Leading Edge

	A	B	C	D
	Frequency, Hz - Leading Edge	Sound Pressue, dBA - Leading Edge	Frequency, Hz - Trailing Edge	Sound Pressue, dBA - Trailing Edge
1				
2	400	73.815	400	71.489
3	500	76.762	500	74.198
4	630	81.814	630	78.903
5	800	86.729	800	83.434
6	1000	84.704	1000	81.099
7	1250	79.081	1250	74.821
8	1600	77.005	1600	71.663
9	2000	77.962	2000	71.285
10	2500	75.426	2500	67.203
11	3150	68.905	3150	58.855
12	4000	66.226	4000	54.301
13	5000	57.355	5000	49.527
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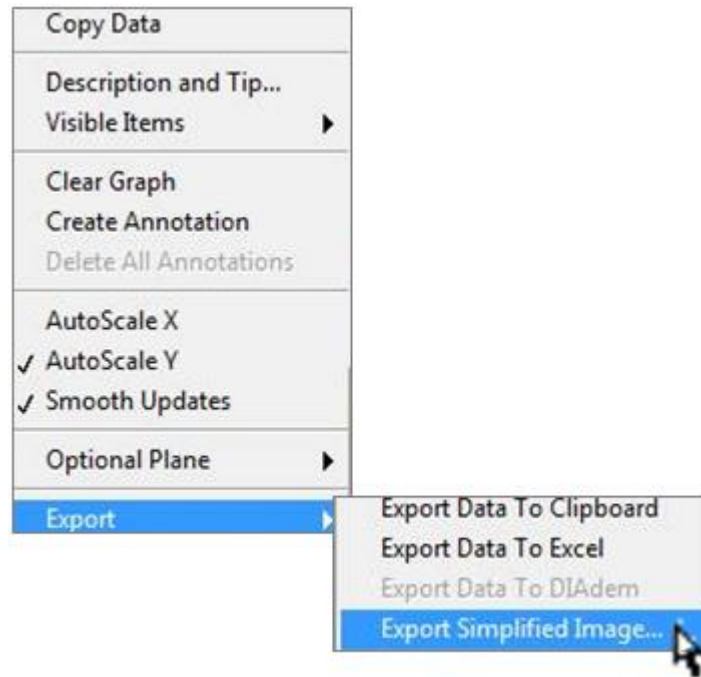
lvtemporary_110836

iii) PI Indices – by definition, the PI Index is the difference between the SPLs and the OBSI levels at each frequency band. The plot on the left and shown in blue is the PI Index for the leading edge probe; the red plot on the right represents the trailing edge PI Index.

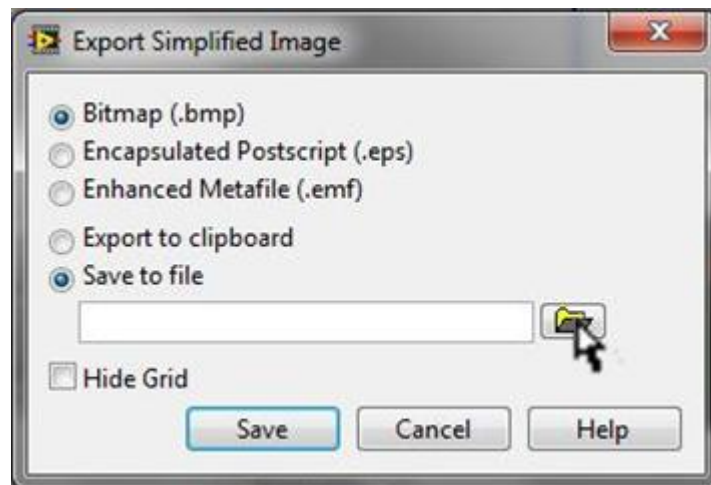


- Similar to exporting individual plot information into Excel, Labview also allows the user to export the image directly to an image file in *.bmp format. To do so, the user must right click on

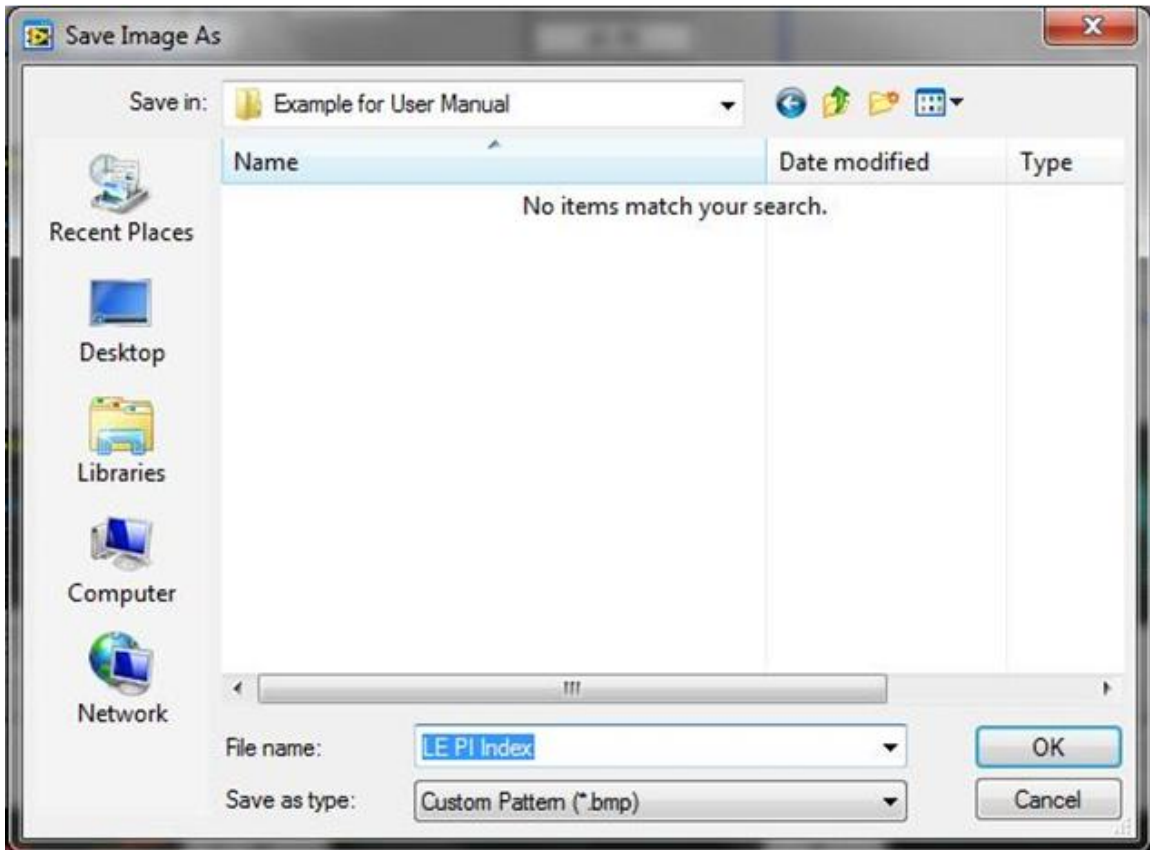
the plot, scroll down to “Export,” and select the option labeled “Export Simplified Image...”



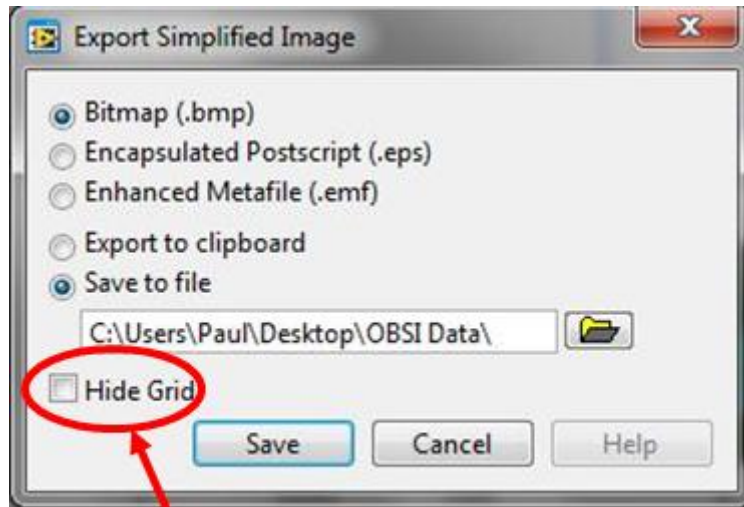
- The user is prompted to select the format for the image (*.bmp is recommended) and the manner in which to use the image (i.e., to “Export to clipboard” or to “Save to file”). By selecting, “Export to clipboard” and pressing “Export,” the user can paste the image in another document. If the user decides to “Save to file,” the directory and name for the image to be saved must also be determined. Press the open folder icon next to the empty, white box under “Save to file.”



- Another “Save Image As” dialogue box pops up. After selecting the folder and name for the file, the user should press “OK” to return to the “Export Simplified Image” box.

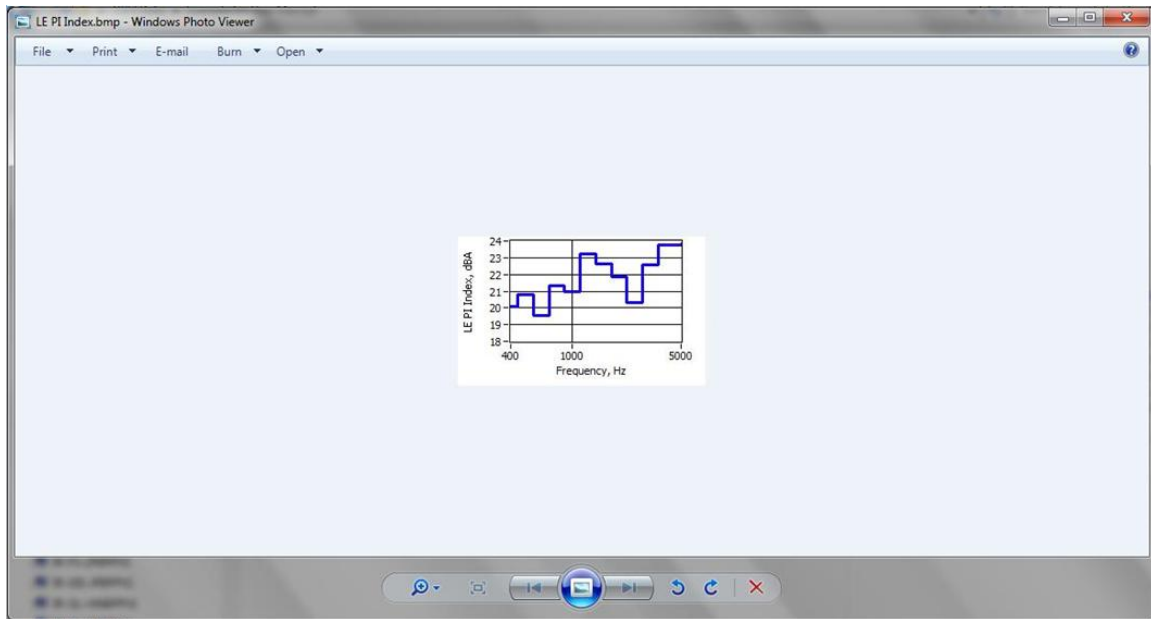


- Before pressing “Save” in the “Export Simplified Image” box and returning to the Labview front panel screen, the user has the option to save the image with or without the gridlines on the plot. Note, this option is also available for the “Export to clipboard” option.

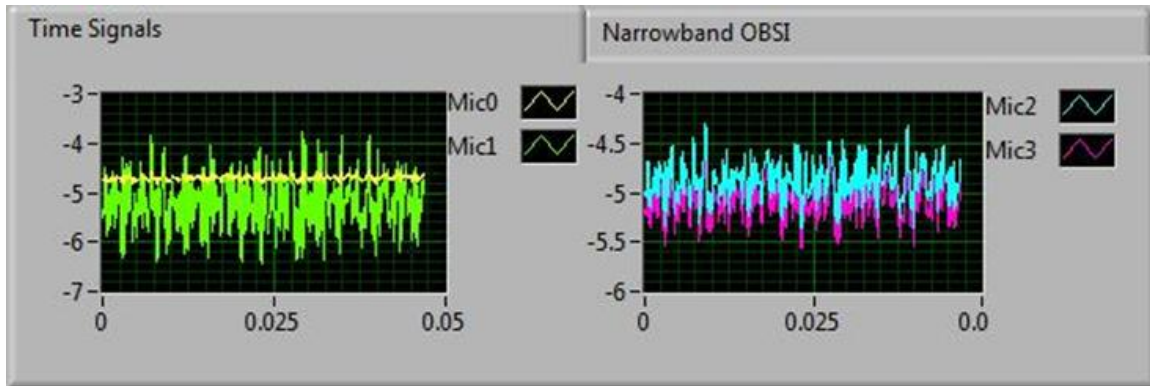


Select to hide gridlines

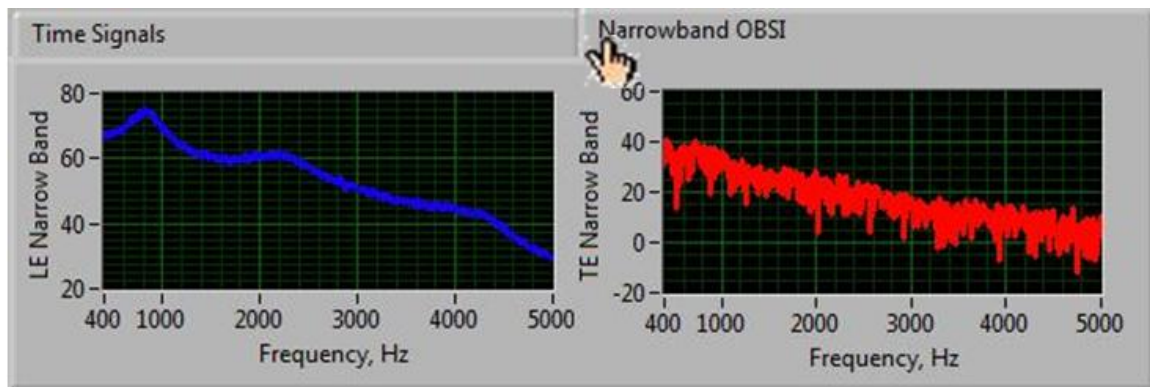
- To view the image just saved, the user can open the image within the chosen directory.



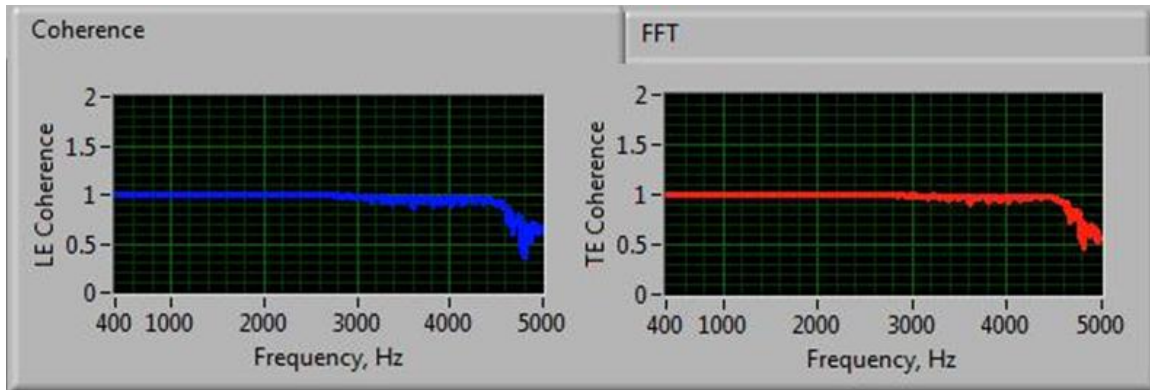
- iv) Time Signals – the first set of plots in the center column of the front panel screen shows the raw Time Signals for each microphone. Upon opening the program, the default settings are such that the tab for Time Signals is automatically displayed and is continuously running while the program is open. The plot on the left shows the time signals for Mic0 in yellow and Mic1 in green (i.e., leading edge probe channels); the cyan-colored plot on the right represents Mic2, while the magenta plot is Mic3 (i.e., trailing edge probe channels).



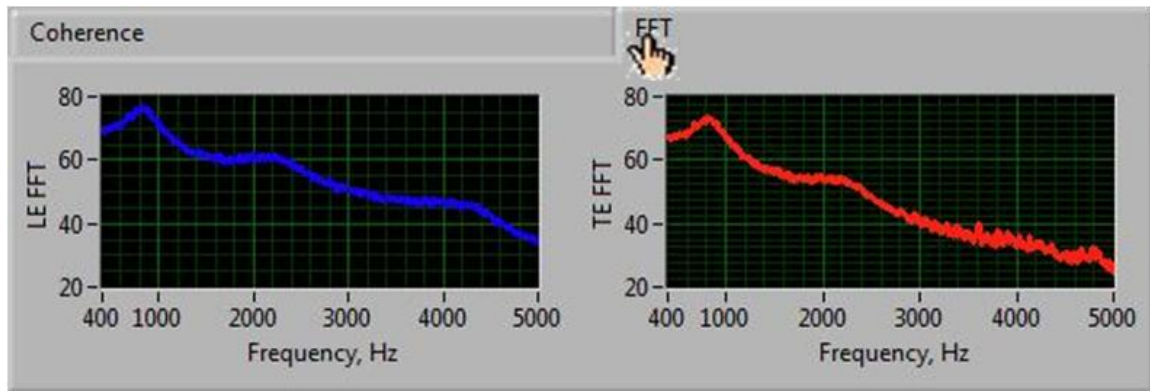
- v) Narrowband OBSI – select the tab labeled Narrowband OBSI located in the same box as the Time Signals. The blue line on the left represents the leading edge probe, and the red line on the right represents the trailing edge probe. Note, the Narrowband OBSI plots are not A-weighted. These figures are generally used for monitoring purposes, but if further analysis of the narrowband results is required, then the user would need to apply A-weighting to the data during post-processing.



- vi) Coherence – below the Time Signals and Narrowband OBSI figures is a box containing the Coherence and FFT plots. By default, the tab for the Coherence plots is automatically displayed. Similar to the PI Index and Narrowband OBSI plots, the leading edge (shown in blue) is on the left, and the trailing edge (shown in red) is on the right. The purpose of the Coherence is to determine how well correlated two measured signals are for each probe. Ideally, the two microphones attached to the same probe should have a coherence of 1.0 throughout the frequency domain. In reality, however, coherence is not this ideal, and coherence does tend to worsen at the higher frequencies. During data acquisition, coherence monitoring acts as the system's operational check.

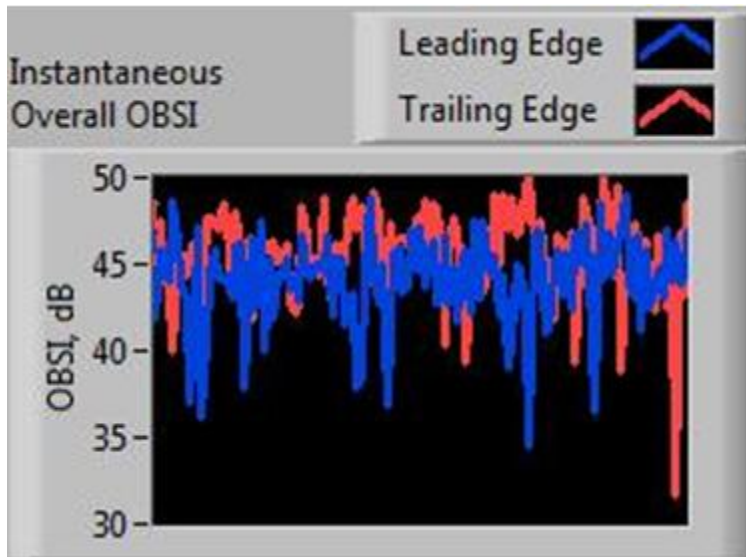


vii) FFT – to display the FFT plots, select the associated tab located in the same box as the Coherence. Once again, the blue line on the left represents the leading edge FFT, and red line on the right represents the trailing edge FFT. Similar to the Narrowband OBSI plots, the FFT plots are not A-weighted.

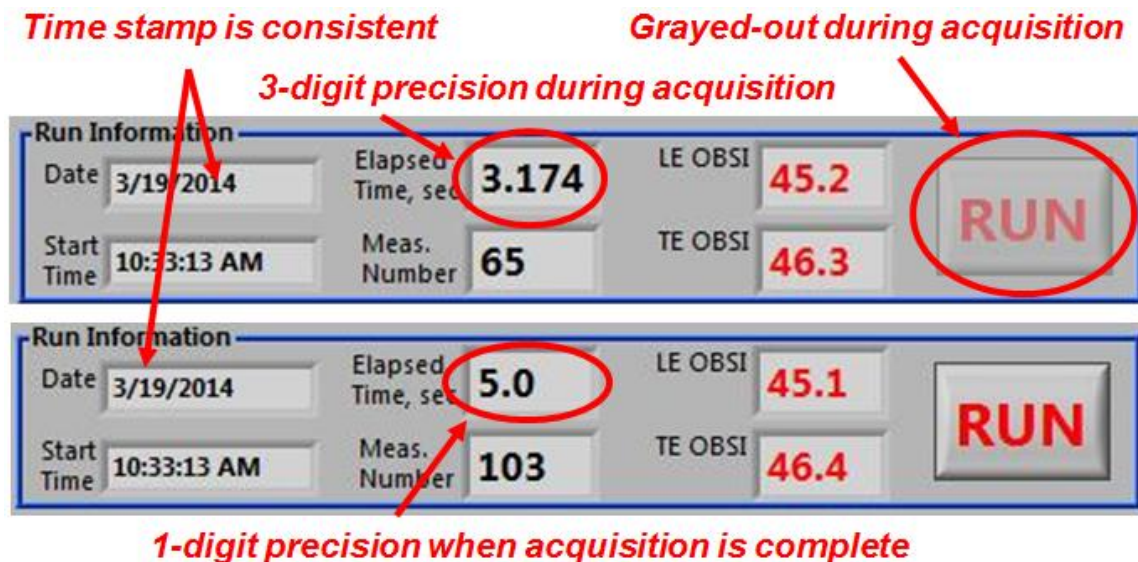


viii) Instantaneous Overall OBSI – the overall instantaneous OBSI levels are calculated by taking the base-10 logarithm of the energy summation for the one-third octave band OBSI spectra. This plot indicates how the overall levels vary in real time, and there is no averaging included for this calculation. This plot runs continuously while the program is activated.

- This can also be used as a system or environmental check. For instance, if the user acquires several consecutive 5-second measurements along a stretch of roadway with the same type of pavement and the measured levels lack consistency, this real-time overall OBSI plot indicates to the user when the discrepancy or discrepancies occurred. This could lead to determining the cause for the bad data (such as a section of damaged roadway surface, etc.)



(c) Also during the 5-second acquisition, the information displayed in the “Run Information” box updates. The “Date” and “Start Time” boxes indicate the moment at which the user pressed “RUN” (or <F5> on the keyboard). The box for the “Elapsed Time, sec” acts as the program’s digital timer, running continuously throughout the 5-second measurement with three-digit precision. Once five seconds has elapsed, the “Elapsed Time, sec” freezes at “5.0” (one-digit precision). The “Meas. Number” acts as a continuous counter throughout the 5 seconds. The “LE OBSI” and “TE OBSI” boxes show the changing overall OBSI levels averaged over the “Elapsed Time, sec.” As is common practice for OBSI data, one-digit precision is displayed in these boxes.



(7) *Data Storage* – there are two methods the user can use to store the data permanently:
a) by manually hitting the “STORE” button; or b) by automatically storing the data by

checking the “Auto Store” check box.

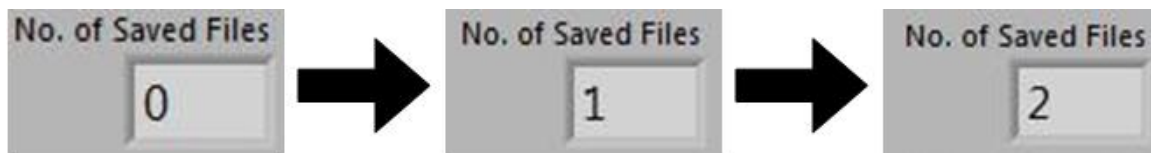
- (a) After each 5-second measurement is complete and the “STORE” button is no longer grayed-out, the user must decide whether to save the measurement run. If the user does want to save the run, then press “STORE” (or <F7> on the keyboard). Note, data from a run is not saved until “STORE” has been selected, and if “RUN” is hit (or <F5> on the keyboard) again without the user pressing “STORE” (or <F7> on the keyboard), then the former run would not be saved.



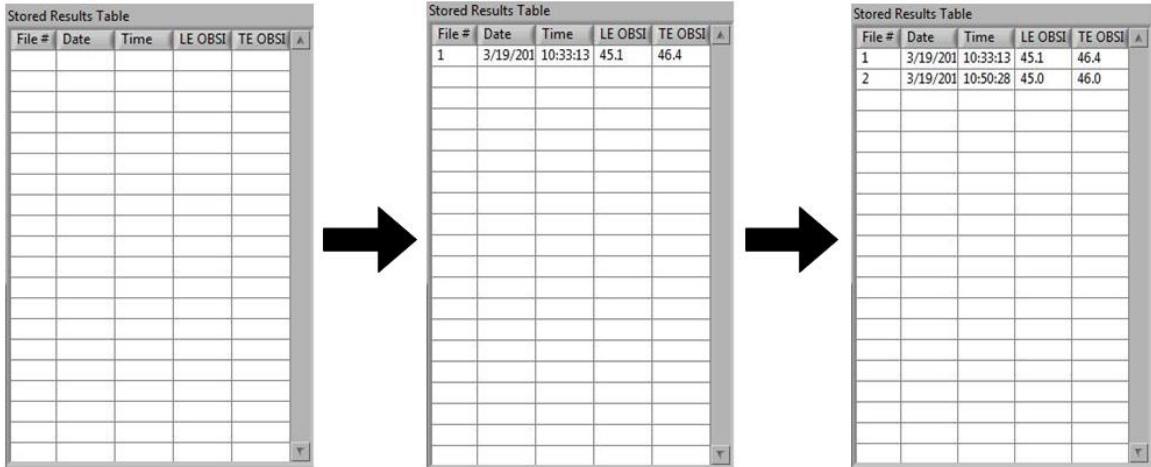
- i) Once the user selects “STORE,” the button is automatically grayed-out. The program is designed to prevent the user from saving duplicate data files, and to such an end, only allows the user to “STORE” data immediately following the 5-second acquisition.



- ii) Each time the user hits “STORE” following data acquisition, the “No. of Saved Files” automatically increases. This box acts as a counter indicating to the user how many files have been permanently stored as *.tdms files during this testing cycle.

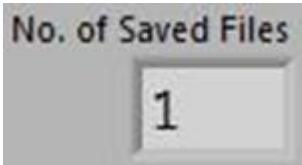
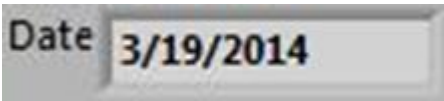
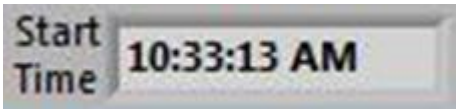




- iii) When “STORE” (or <F7> on the keyboard) is pressed, the data from that corresponding run is saved as a *.tdms file and the results are summarized in the “Stored Results Table” on the right side of the front panel. There are five columns of data, each of which relates to other results boxes displayed on the front panel. While the measurements in the blue “Run Information” and “Stored Data Files Information boxes display the results for the current test run, the “Stored Results Table” shows the measurement history of all the stored runs during a given testing period. With each new measurement stored, a new line is appended to the results table.



- The following table provides a brief description of the “Stored Results Table” information.

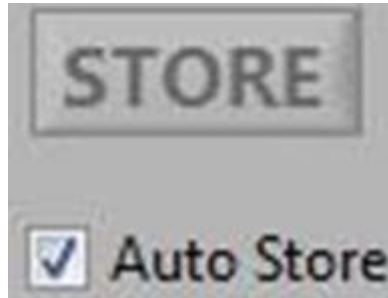
File #	Date	Time	LE OBSI	TE OBSI
1	3/19/201	10:33:13	45.1	46.4

Column Headings	Corresponding Information Boxes	Description
File #		Number of files stored during the given testing period
Date		Date when "RUN" is pressed (or <F5> is hit on the keyboard)
Start Time		Time when "RUN" is pressed (or <F5> is hit on the keyboard)
LE OBSI		5-second overall OBSI level at the leading edge probe
TE OBSI		5-second overall OBSI level at the trailing edge probe

iv) As mentioned above, Labview stores the results as *.tdms files in either the user-specified directory and with the user-specified name or as "test" in the *c://temp* folder. The Labview program is designed to save all results separate from the program itself so once the user hits "STORE" (or <F7> on the keyboard), the files are saved until the user goes into the directory where the *.tdms files are stored and deletes them. Unless a licensed version of Labview is obtained by the user, *.tdms files cannot be read outside of the executable program file.

(b) If the user checked the "Auto Store" check box prior to hitting "RUN," the 5-second run data will automatically be permanently stored after each 5-second measurement is complete. Each of the above steps *i)* through *iv)* that occurred

with the manual “STORE” button will also occur with the “Auto Store” feature. The “Auto Store” feature can be activated and de-activated at any time during a test, except during a 5-second run. Note, while the “Auto Store” check box is checked, the “STORE” button will be grayed-out.



- (c) In addition to storing the 5-second run data to *.tdms files, the user can also store the “Stored Results Table” separately. The “Stored Results Table” is a quick summary reference that can provide a quick summary of the overall levels without having to export each individual run. To save the “Stored Results Table,” simply press the “SAVE TABLE” button. All of the data stored permanently up to the point when the user pressed “SAVE TABLE” will be saved under a file name as such:

[base filename]_Results_[yyyymmdd]_[hhmmss].tdms. The date and time will reflect the time when the user hit “SAVE TABLE.”



- i) If the program is closed prior to the user pressing “SAVE TABLE,” then the results table *.tdms file will not be saved. The run data permanently stored up to that point will be saved, but the results table will not be saved in its own separate *.tdms file.
- (8) *Saving the Program* – storing the measurement run data when hitting “STORE” (or hitting <F7> on the keyboard) is independent from saving the program. Hitting “STORE” (or hitting <F7> on the keyboard) permanently stores the test data in *.tdms format, but the program itself cannot be altered in the executable form. Unless the user obtains a licensed version of Labview, no changes can be made to the program.
- (9) *Clearing Display Screen* – the most direct way to clear the display screen is to select the “CLEAR TABLE” button (or pressing <F2> on the keyboard) in the “Stored Data

Files Information.” This deletes each line of data shown in the “Stored Results Table” and resets the “No. of Saved Files” back to “0.” While the program remains open, the plots nor the data displayed in any of the other boxes on the screen will be reset, however. Other ways to automatically clear the display table are discussed below.

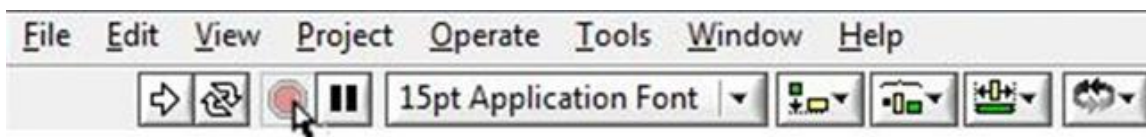


- (a) If the user decides to change the “Output filename template” directory or base filename, then the “Stored Results Table” and the “No. of Saved Files” will automatically be cleared. This does not mean that previously displayed data has been deleted. Once a *.tdms file has been created, it cannot be deleted within this program. The clearing of the table regards the display screen only.
- (10) *Deactivating the Program* – when the program is deactivated, Labview will close automatically. There are three ways to deactivate the program. These are discussed below.

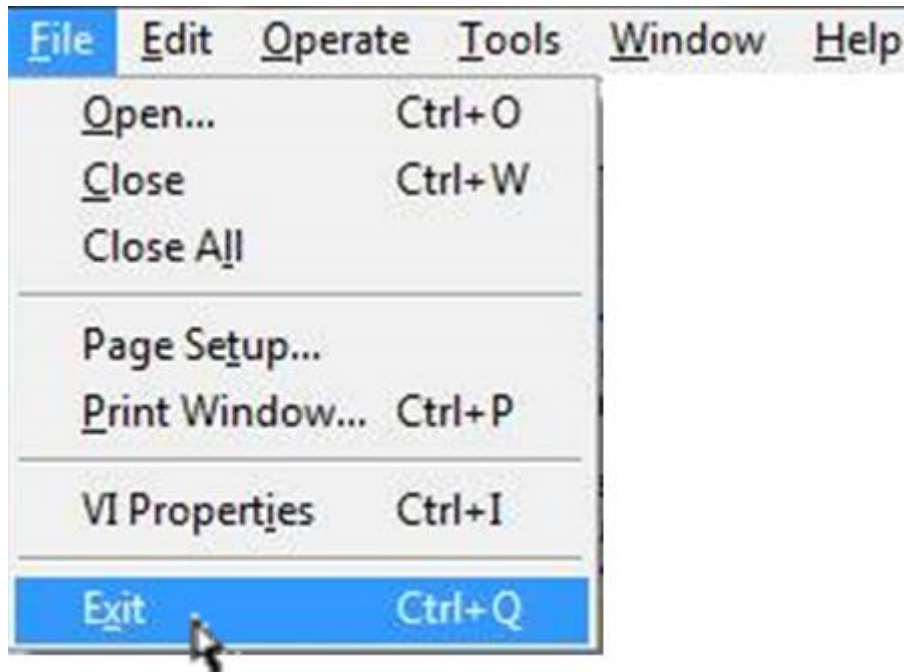
- (a) The user can terminate the program by hitting “STOP” on the front panel (or selecting <F12> on the keyboard). This stops the acquisition and closes the executable program. The “STOP” button is not included within any of the main tabs (i.e., **Test Procedure**, **Calibration**, and **Data Export**) and can be selected while any of these tabs are displayed.



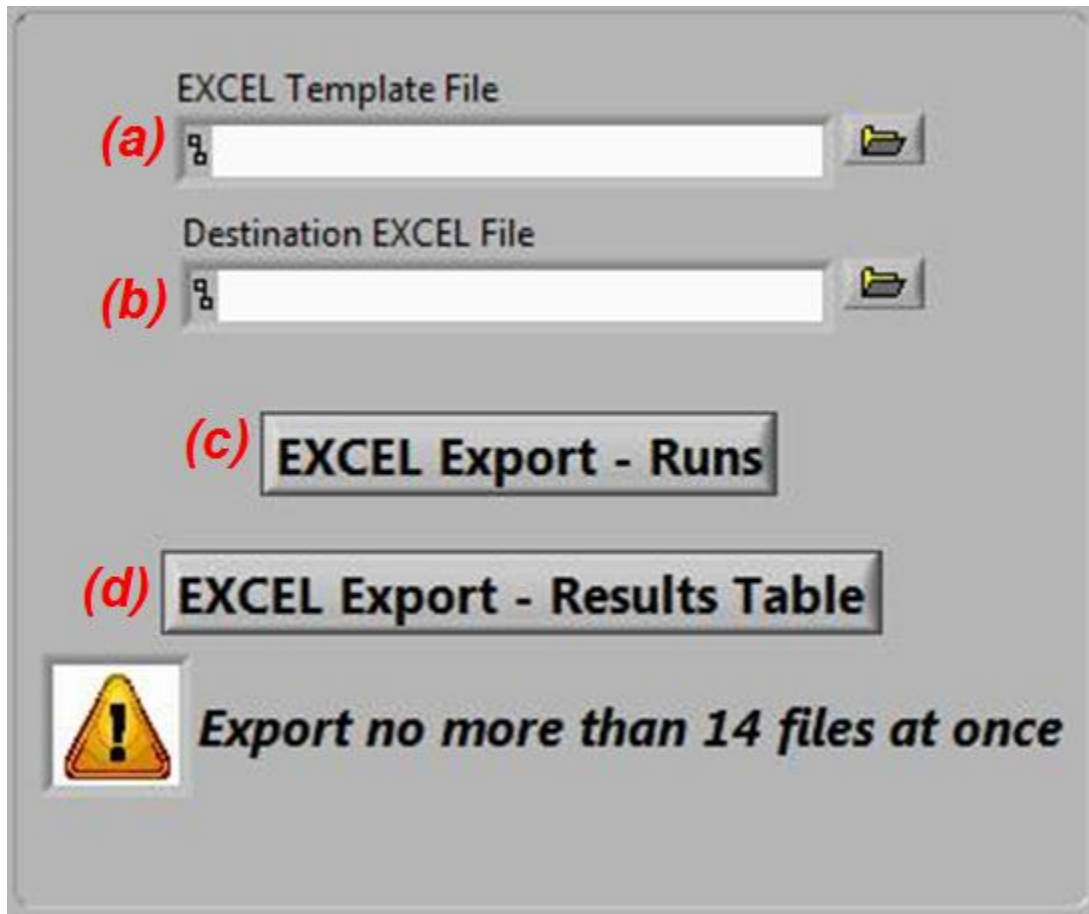
- (b) The red octagon along the control panel in the upper left-hand corner of the screen can also be used to stop the acquisition and terminate the program.



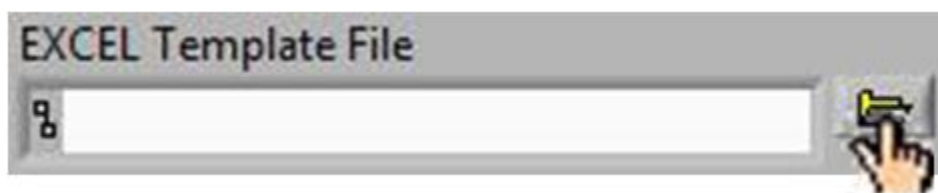
- (c) The program can also be stopped by selecting “File” → “Exit” (or hitting <Ctrl> + <Q> on the keyboard) from the control panel at the top left-hand corner of the screen.



(11) *Data Export to Microsoft Excel* – select the **Data Export** tab at the top of the screen to open the window. The user can export the data saved as *.tdms files into Microsoft Excel and/or as an audible *.wav file. In both cases, the user has the option to export the data immediately following data acquisition or at a later time. However, to use the export feature within this program, the channels must be connected to the computer (just like it was for the data acquisition), or an error message will appear (i.e., “Error -201003” shown above in Step 1). Note, there is also a separate exporting executable file that does not require the microphone acquisition box to be attached while running. The exporting features are the same for this separate executable program. The following instructions provide the steps for exporting to Microsoft Excel. The program is designed to automate as much of the data processing as possible. Step 12 discusses exporting to *.wav files.

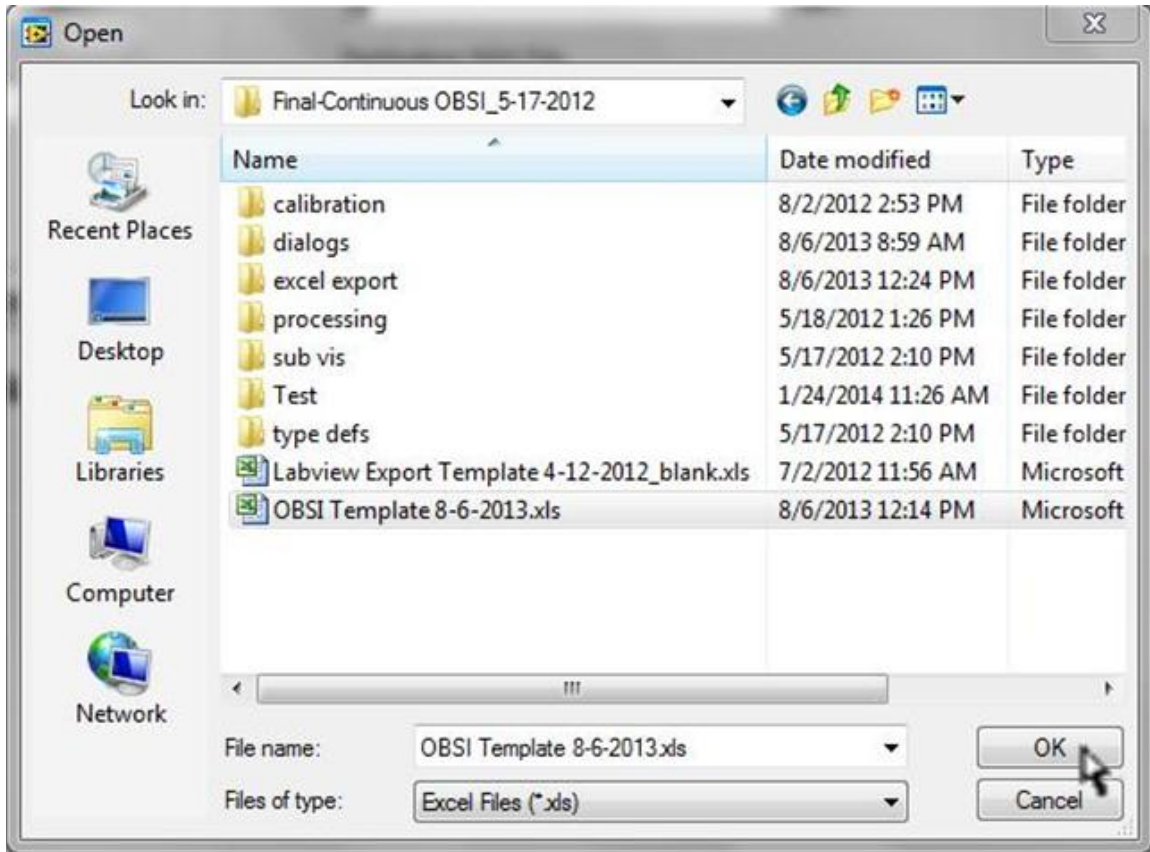


- (a) EXCEL Template File – a Microsoft Excel template was also developed as part of the Labview OBSI package. To select the template file, click on the open-folder button to the right of the empty, white box.



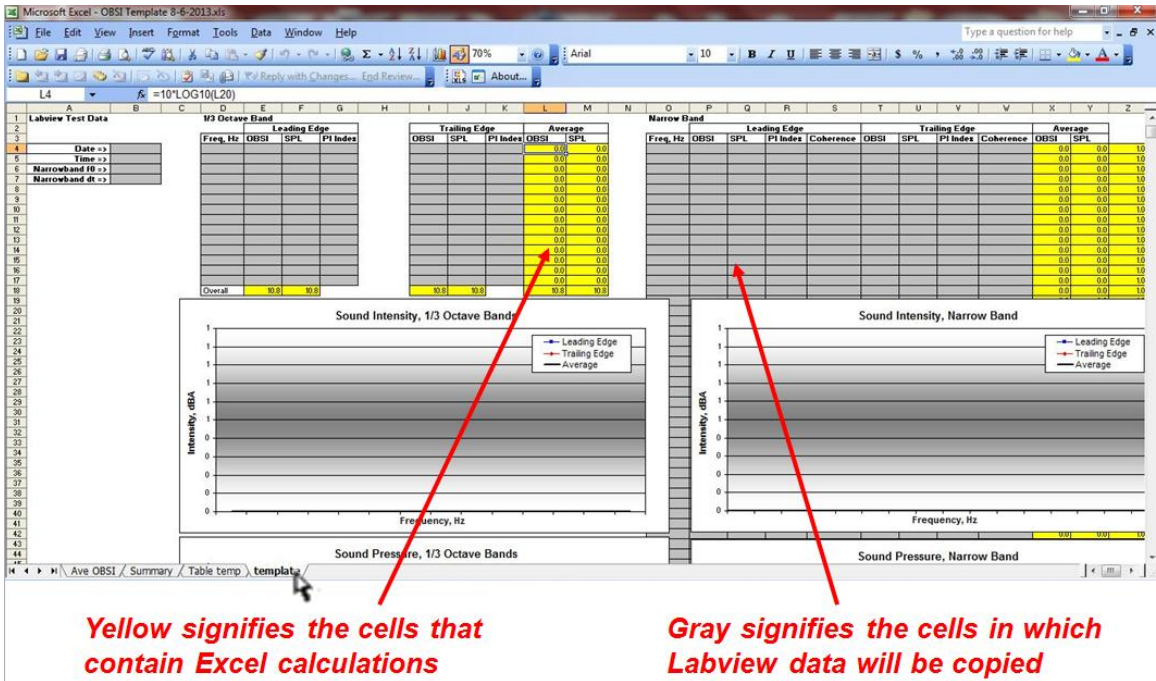
- ii) A pop-up window will appear and prompt the user to select the Excel template file. The template can be found in the same folder as the Labview program files (although the exporting operation would not be affected if the template was located in another directory or saved under another name). The program is designed to make a copy of this template file, rename the file per user choosing, and save the new file in a user-defined directory; therefore, the same template can be used for all data exporting. The Excel template file is called “OBSI Template 8-6-2013.xls.” After selecting the file, hit “OK” to return to the **Data Export** front panel screen. Note, the template file is *.xls due to the version of Excel used on

the computer that Labview was programmed on; however, if the user's computer has a more recent version of Excel (e.g., *.xlsx) then it is recommended that the user resave the template in the most recent format. Changing the template format will not affect the Excel exporting feature of the Labview program.

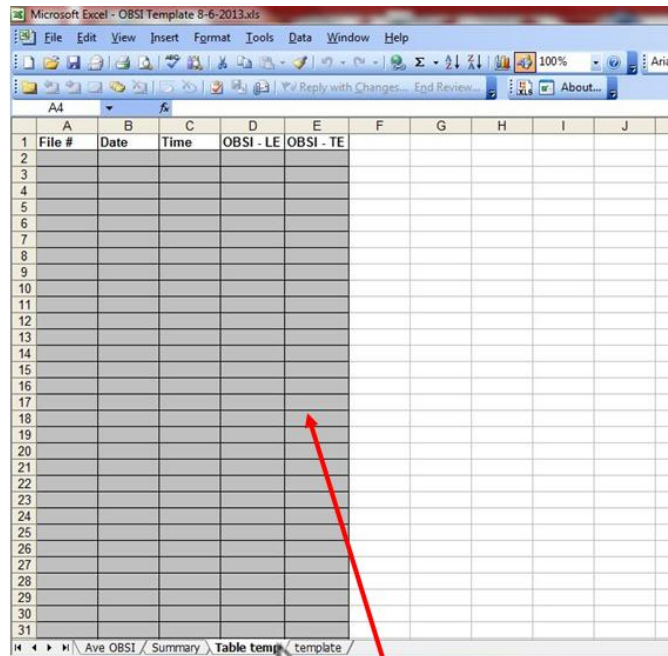


iii) The Excel template file has four tabs: “Ave OBSI,” “Summary,” “template,” and “Table temp.”

- The “template” tab shows how the run data stored in each *.tdms file would be presented once exported to Excel. When the user exports the run data, Labview is programmed to put the calculated data from an individual run into the designated gray cells. The yellow cells contain Excel formulas designed to calculate the average spectra and overall OBSI values. The plots shown on the worksheet include Sound Intensity, Sound Pressure, and PI Index in the one-third octave band and narrowband frequency domains, as well as the Coherence in the narrowband domain. Once the data is copied into the gray cells, the plots will automatically update.

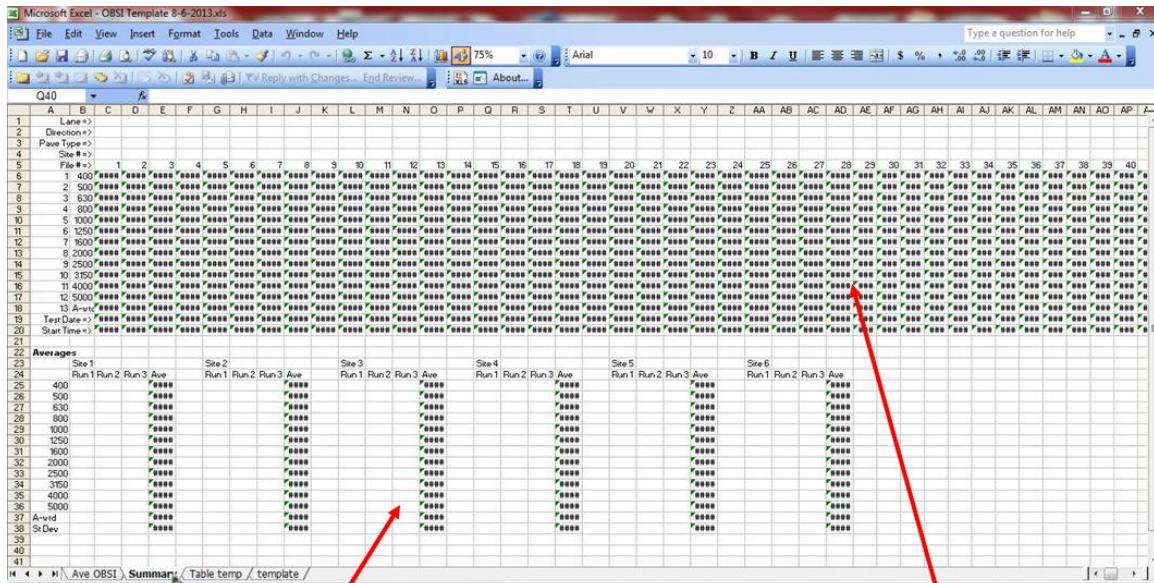


- The “Table temp” tab shows how the “Stored Results Table” is exported into Excel. When the user exports the “Stored Results Table,” Labview is programmed to put the summary results shown on the **Test Procedure** main screen into the designated gray cells.



Gray signifies the cells in which Labview data will be copied

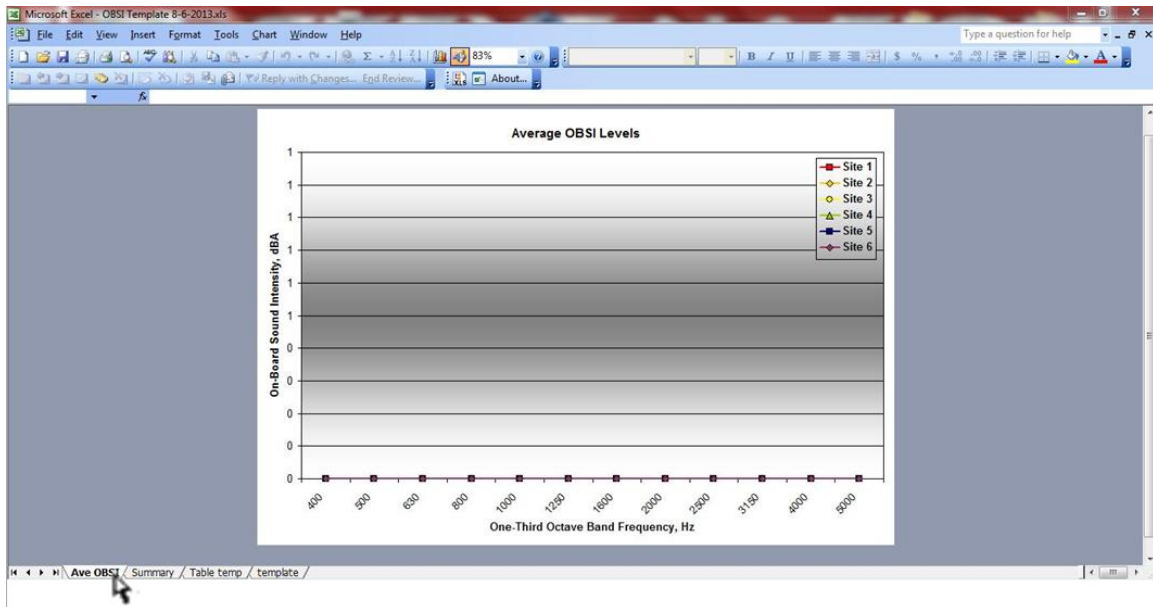
- Within the worksheet labeled “Summary,” the cells contain Excel formulas that return the average OBSI spectra and overall levels calculated in the tabs containing testing data from each run. Obviously, the Excel template does not contain any data, but once the *.tdms files are exported to Excel, this worksheet would automatically update. Since each test site is different and the number of runs taken varies per project, the user would be responsible for updating the run averages shown in rows 22 through 38.



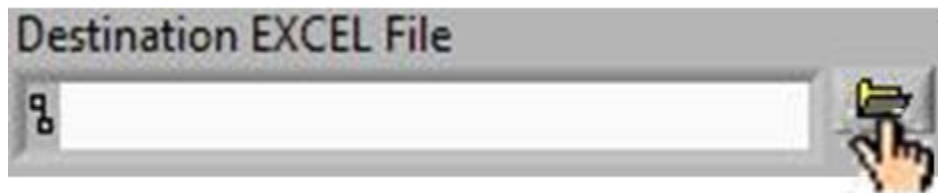
Averages should be adjusted by user & would vary depending upon project

Contain Excel calculations that call OBSI data from tabs containing test measurement information

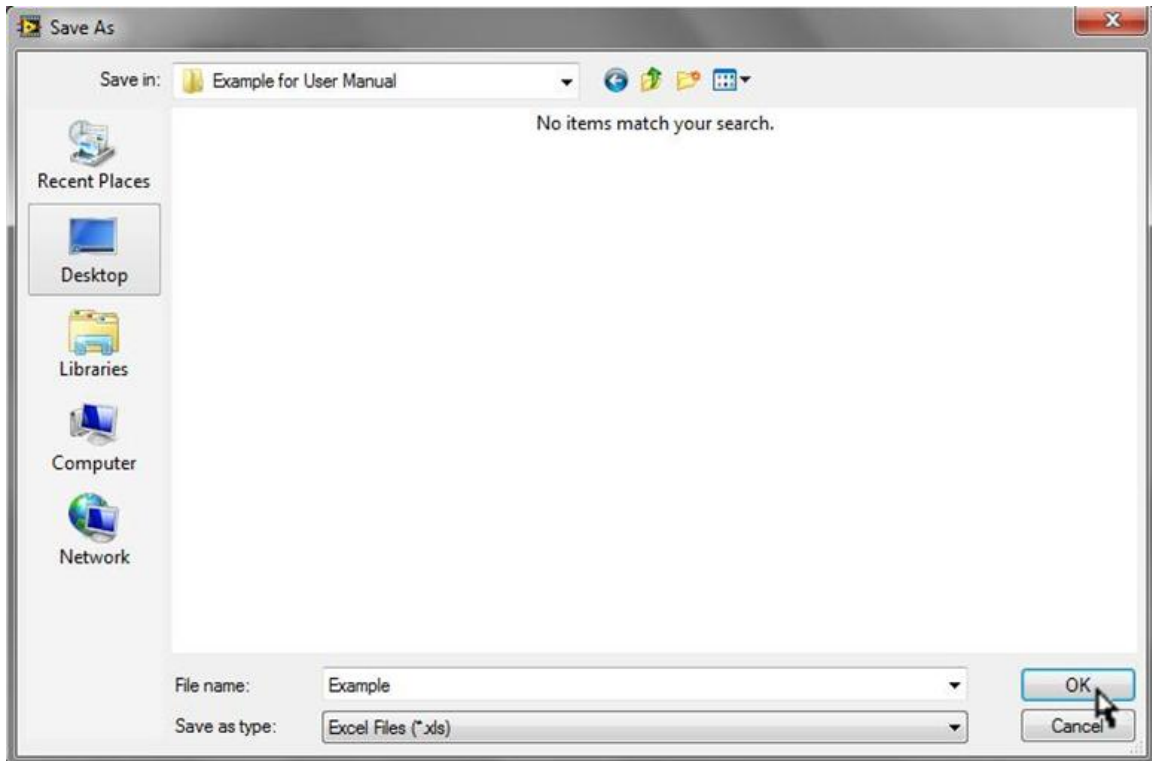
- The final worksheet, labeled “Ave OBSI,” shows the summary plot of the run-averaged OBSI spectra calculated in the “Summary” tab in rows 22 through 38. This plot can be modified per user preference.



(b) Destination EXCEL File – this is where the user can select the name for the new file containing the test data and the directory in which to save the new file. Click on the open-folder button to the right of the empty, white box.



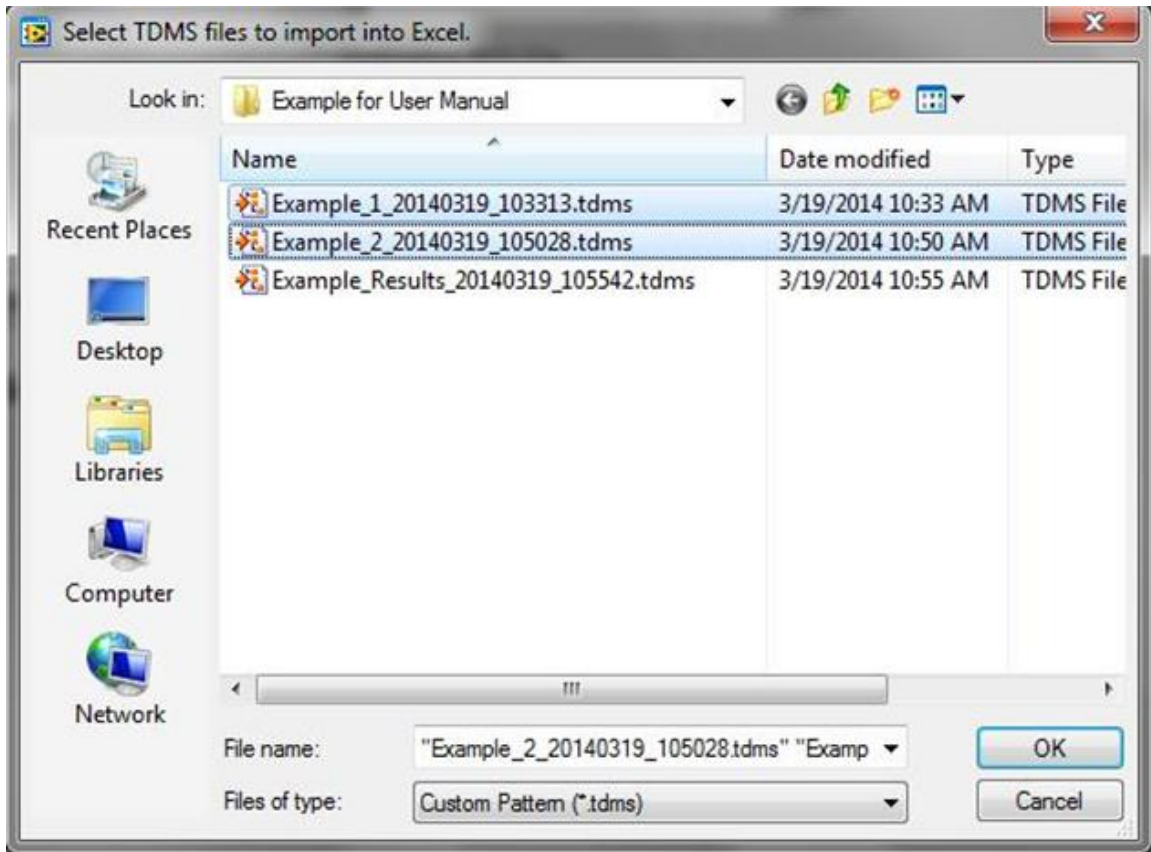
i) A pop-up window will appear and prompt the user to select new directory location and Microsoft Excel file name for the new file containing data. While not required, it is recommended that the new Excel file be located in the same directory as the *.tdms files that are to be exported. After the user selects a filename and directory, hit “OK” to return to the **Data Export** front panel screen.



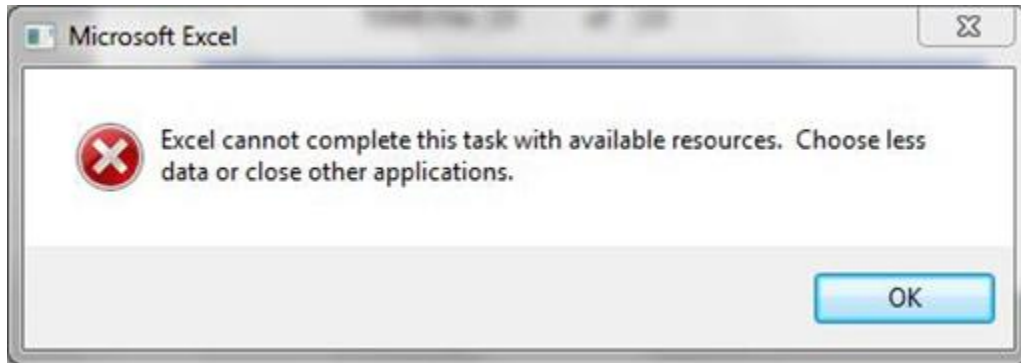
- (c) EXCEL Export – Runs – after selecting the Excel template file, the filename, and the directory for the new, populated Excel file, the user has the option to either export individual run data or the summary “Stored Results Table.” If the user wants to export individual run data, the user should select the “EXCEL Export – Runs” button (or hit <F10> on the keyboard) to select the *.tdms files to export.



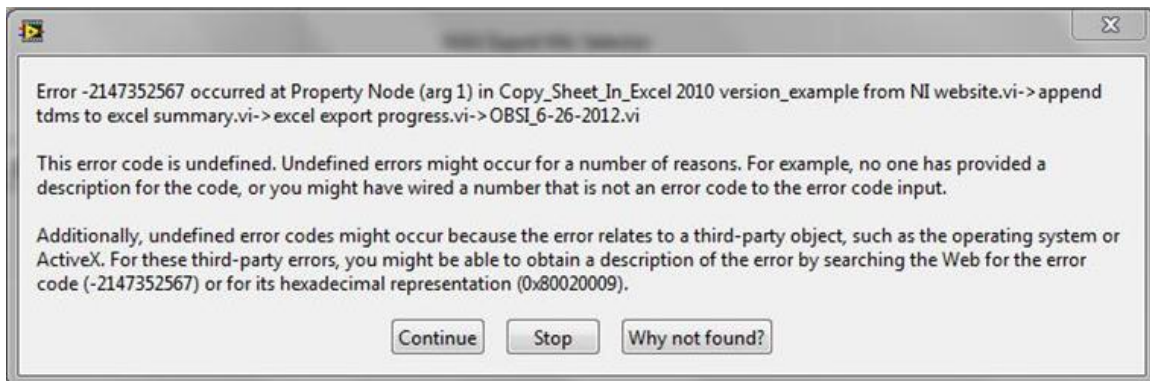
- i) A pop-up window will appear and prompt the user to select all *.tdms files to export to Excel. After the user selects all *.tdms files, hit “OK” to close the window.



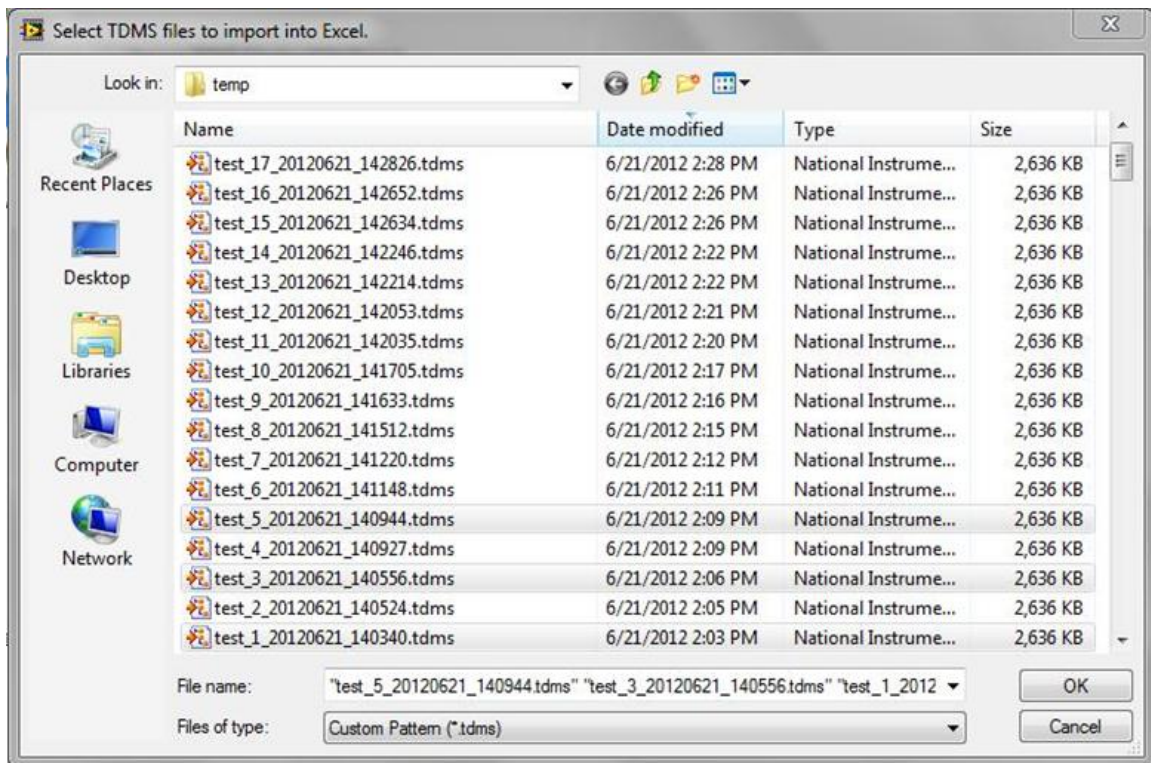
- If the user is using the Excel template file in *.xls format, then the number of runs Labview can export at one time is limited to 14; hence, the warning statement on the **Data Export** screen. The *.tdms files contain a lot of information. So when the *.tdms data files are copied into the template, the size of the Excel files are quite large. Given this information, the user is limited to the number of *.tdms files that can be exported into a single file. As mentioned above, the maximum number of files is 14. This may seem small, but considering the relative quickness of the exporting process and the automated data processing programmed into Labview and the Excel template, exporting 14 files at a time still improves the processing time required when using other systems. Below is the error message that would appear if the user attempted to export more than 14 *.tdms files into an Excel template with the format *.xls. If the user is using an Excel template of the format *.xlsx, then the user can export up to around 60 files at once.



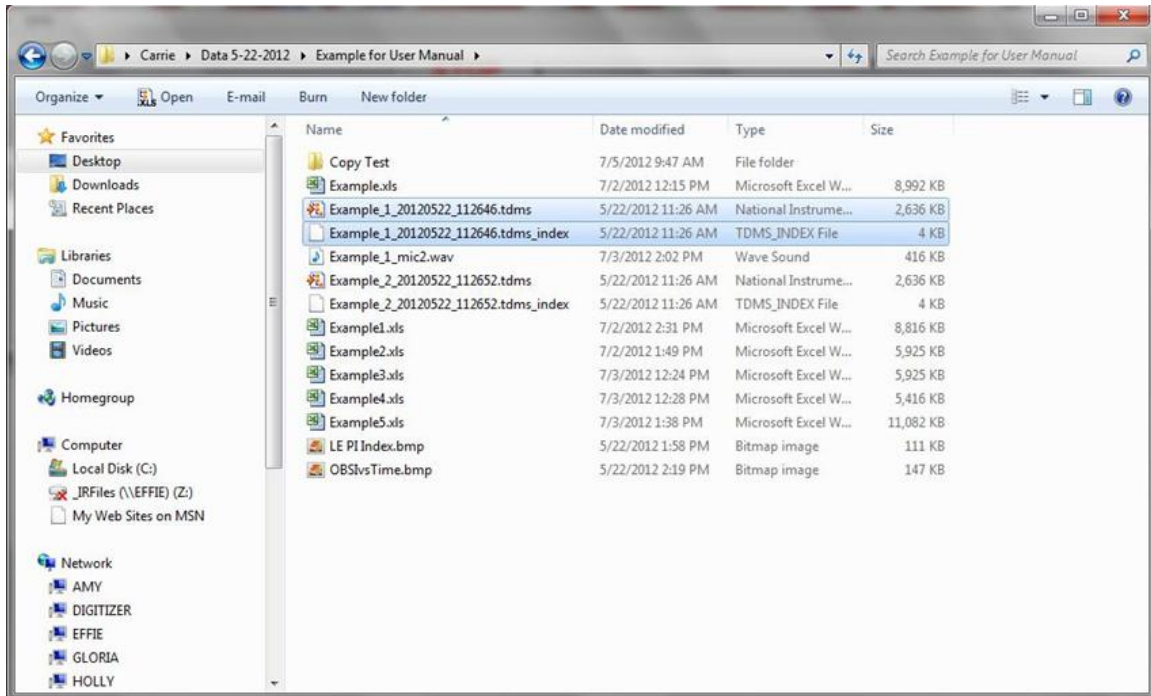
- The program is designed to copy the “template” worksheet tab within the Excel template and rename the copied tab the file # associated with the given *.tdms file being exported. That is, for the data file called “Example_1_20120522_112646.tdms,” all results would be copied into the worksheet tab labeled “1.” Likewise, if the file called “Test_1_20120522_112652.tdms” was exported to Excel, the tab would also be labeled “1.” So if the user tried to export both of these files into the same Excel spreadsheet, the Labview program would return an error message like the one below, prompting the user to either select different files or abort the program.



- If the user concludes that some runs were “bad data,” those associated *.tdms files do not have to be exported with the rest of the data. For instance, if the user stored five runs of data but only wants to export the best three runs (file #s 1, 3, and 5), then the user should only choose the corresponding three files by holding down <Ctrl> on the keyboard while selecting the *.tdms files using the mouse. The numerical worksheet names would remain consistent with the chosen file #s. That is, the Excel file would have tabs labeled “1,” “3,” and “5.”



- Also note that *.tdms files located in different directories cannot be exported into the same Excel file. All data to be exported simultaneously should be located in the same folder. If the user does want to export *.tdms files from different folders into the same Excel file, then the *.tdms files and the corresponding index files should be copied into the same folder.



- It should also be noted that in the figures above that show *.tdms files in their corresponding directories, there is an orange symbol that designates the file as a *.tdms. This symbol will not show up on most computers. The computer from which these images were taken has a full Labview license. On computers without a Labview license that will just run the executable version, the following symbol that looks like a paper with the corner folded down will appear.

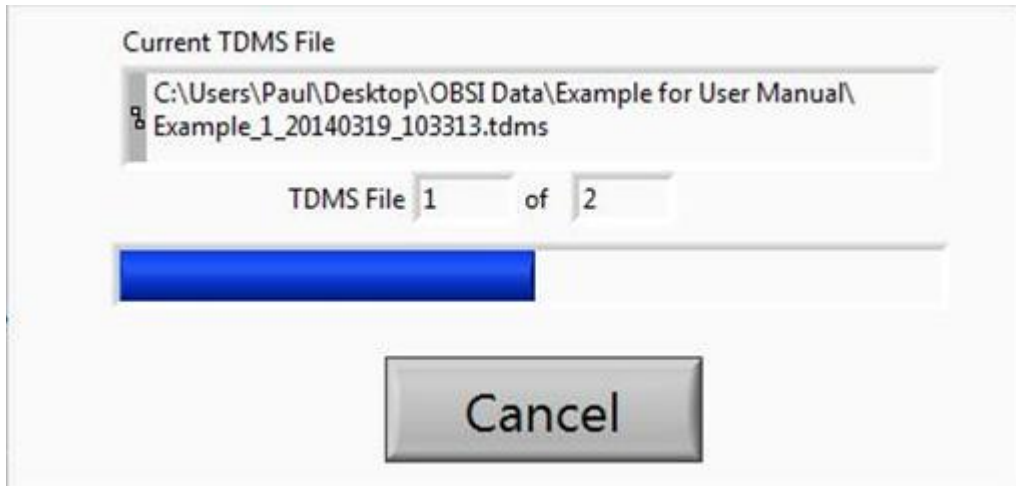
Computer with Labview license →



Computer without Labview license →



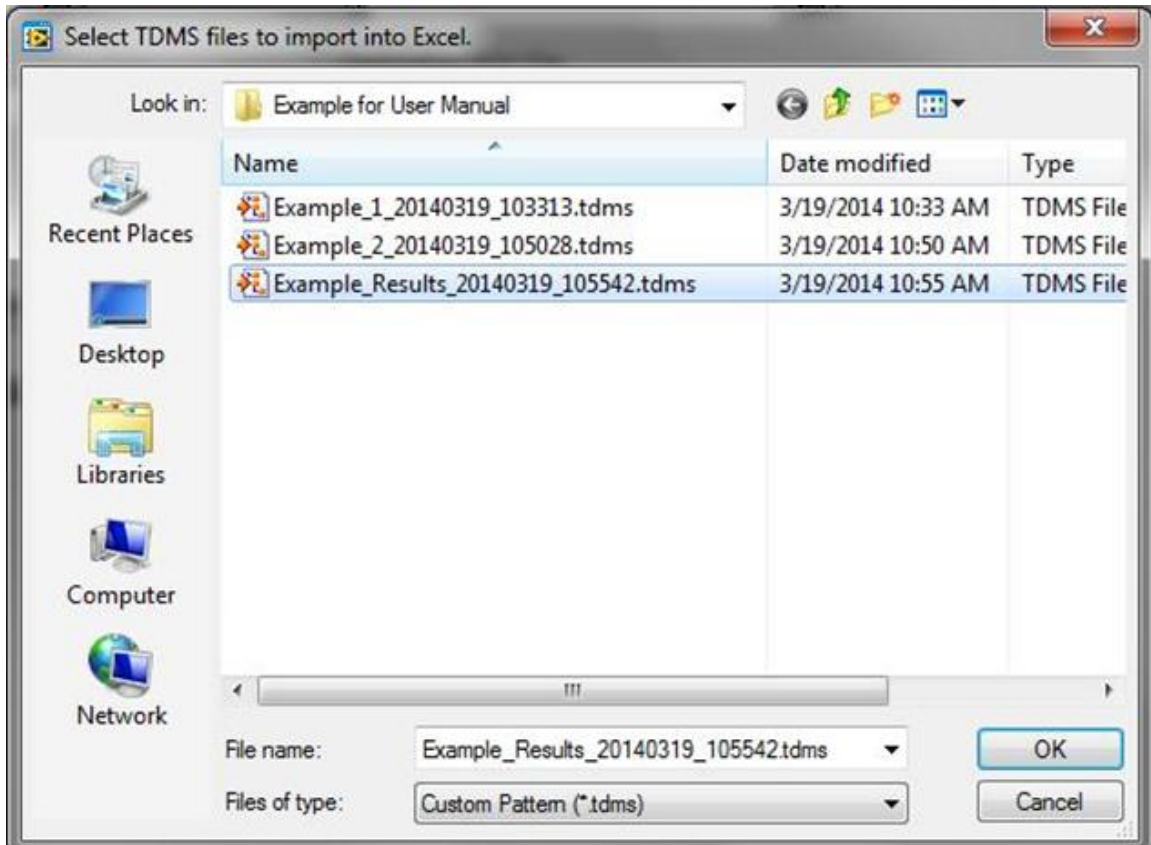
- ii) After the user selects the *.tdms files to export and hits “OK,” a pop-up window appears showing the progress of the export operation. Once all the selected *.tdms files have been exported, the progress bar will go away and return the user to the **Data Export** front panel screen.



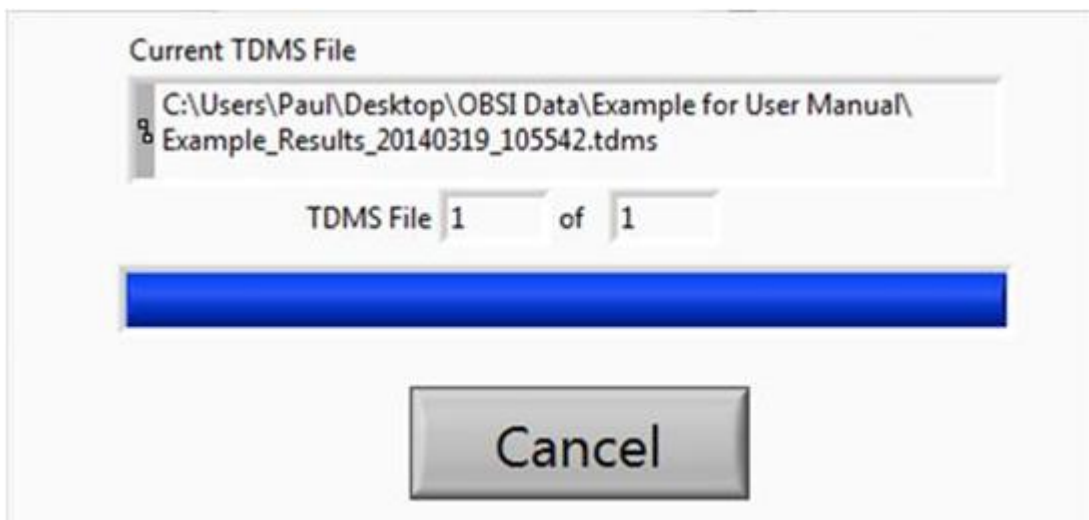
- (d) EXCEL Export – Results Table – after selecting the Excel template file, the filename (e.g., Example-Results.xls), and the directory for the new, populated Excel file, the user also has the option to export the summary “Stored Results Table.” If the user wants to export the summary table, the user should select the “EXCEL Export – Results Table” button to select the *.tdms files to export.



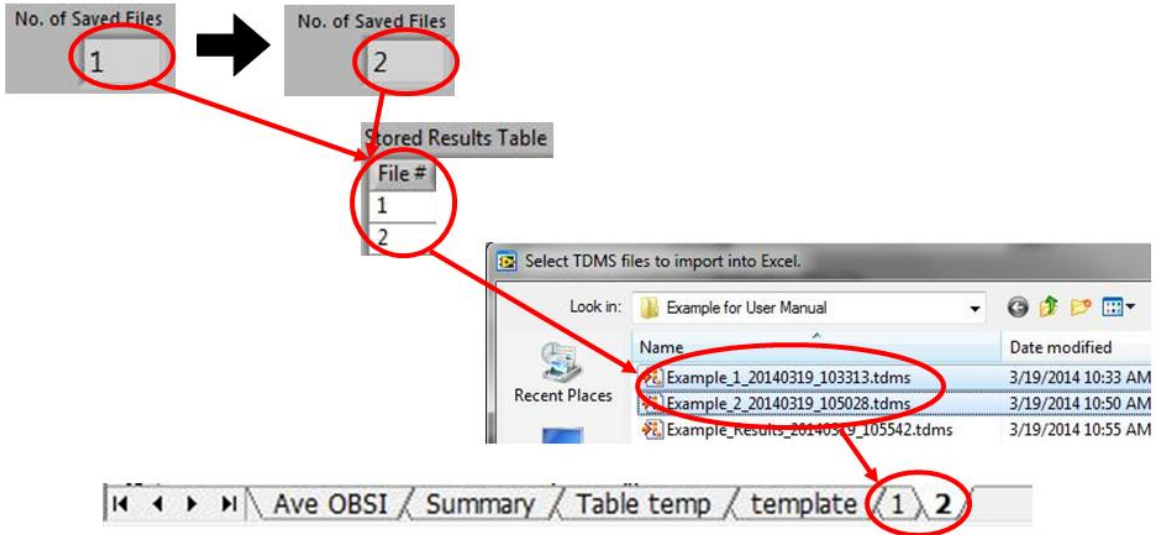
- i) A pop-up window will appear and prompt the user to Results *.tdms file to export to Excel. After the user makes the selection of the *.tdms file, hit “OK” to close the window. Note, only one Results *.tdms file can be exported at a time so only one file can be selected.



- ii) After the user selects the *.tdms file to export and hits “OK,” a pop-up window appears showing the progress of the export operation. Once the summary results table from the selected *.tdms file has been exported, the progress bar will go away and return the user to the **Data Export** front panel screen.



(e) If the user goes to the directory in which the new Excel file containing the run data is located and opens the file, then the user would find two additional tabs located after the four original tabs from the Excel template. As mentioned above, the two new worksheet tab labels correlate to the file #s assigned to the *.tdms files during data acquisition.



i) Tab “1,” as shown below, is structured the same as the “template” tab we previously discussed, but with the results from Example_1_20140319_103313.tdms filled in the appropriate cells (shown in gray). The yellow Excel-formula cells and the plots update automatically. Note, tab “2” would be similar to tab “1” just with data from Example_2_20140319_105028.



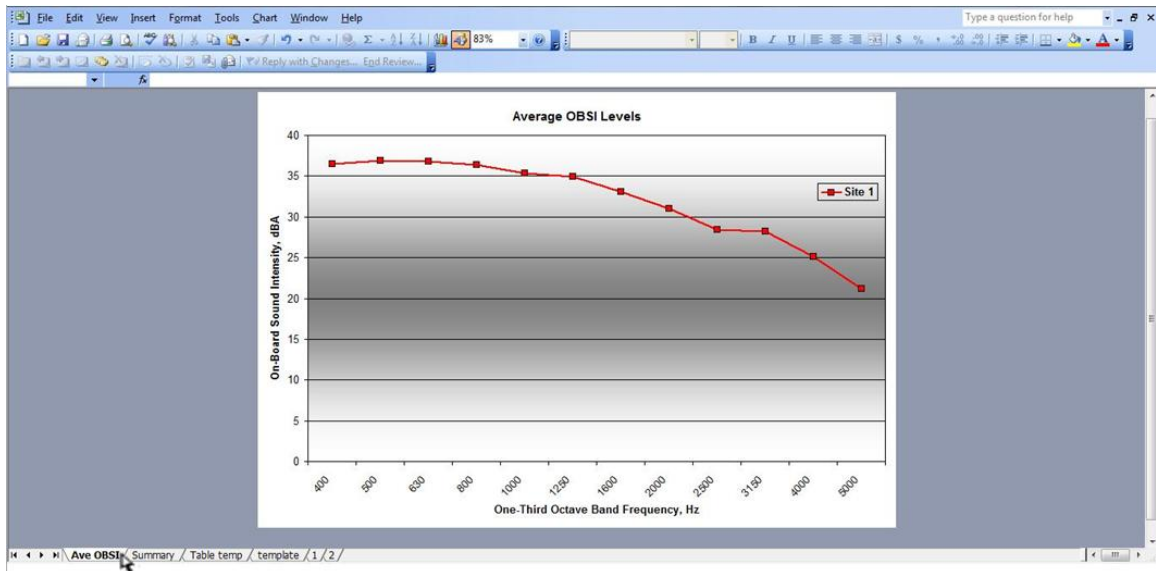
ii) The “Summary” worksheet has also been updated. Since there are only two results tabs (i.e., “1” and “2”), only columns C and D contain data. This data correlates to the average OBSI between the leading edge and trailing edge data. The *Averages* calculation section shown in rows 22 through 38 should be updated by the user to appropriately represent this example. Also note that the user can update rows 1 through 4 with information pertaining to the test runs.

The screenshot shows an Excel spreadsheet with the following data:

	A	B	C	D	E	F	G	H	I	J	K
1	Lane =>										
2	Direction =>										
3	Pave Type =>										
4	Site # =>										
5	File # =>		1	2	3	4	5	6	7	8	9
6	1	400	36.2	36.7	####	####	####	####	####	####	####
7	2	500	37.1	36.8	####	####	####	####	####	####	####
8	3	630	37.6	36.0	####	####	####	####	####	####	####
9	4	800	36.1	36.7	####	####	####	####	####	####	####
10	5	1000	35.7	35.1	####	####	####	####	####	####	####
11	6	1250	34.5	35.3	####	####	####	####	####	####	####
12	7	1600	33.2	33.0	####	####	####	####	####	####	####
13	8	2000	31.0	31.0	####	####	####	####	####	####	####
14	9	2500	28.4	28.4	####	####	####	####	####	####	####
15	10	3150	28.6	27.9	####	####	####	####	####	####	####
16	11	4000	25.2	24.9	####	####	####	####	####	####	####
17	12	5000	21.0	21.4	####	####	####	####	####	####	####
18	13	A-wtc	44.9	44.7	####	####	####	####	####	####	####
19	Test Date =>	2014-1	2014-1	####	####	####	####	####	####	####	####
20	Start Time =>	10:33:	10:50:	####	####	####	####	####	####	####	####
21											
22	Averages										
23		Site 1				Site 2					S
24		Run 1	Run 2	Run 3	Ave	Run 1	Run 2	Run 3	Ave		R
25	400	36.2	36.7		36.4				####		
26	500	37.1	36.8		36.9				####		
27	630	37.6	36.0		36.8				####		
28	800	36.1	36.7		36.4				####		
29	1000	35.7	35.1		35.4				####		
30	1250	34.5	35.3		34.9				####		
31	1600	33.2	33.0		33.1				####		
32	2000	31.0	31.0		31.0				####		
33	2500	28.4	28.4		28.4				####		
34	3150	28.6	27.9		28.2				####		
35	4000	25.2	24.9		25.1				####		
36	5000	21.0	21.4		21.2				####		
37	A-wtd	44.9	44.7		44.8				####		
38	St Dev				0.1				####		
39											
40											
41											

iii) As discussed above, the “Ave OBSI” worksheet tab plots the *Averages* calculation in the “Summary” tab, rows 22 through 38. For this example,

there was only one site measured; so the plot in “Ave OBSI” contains only one data set.

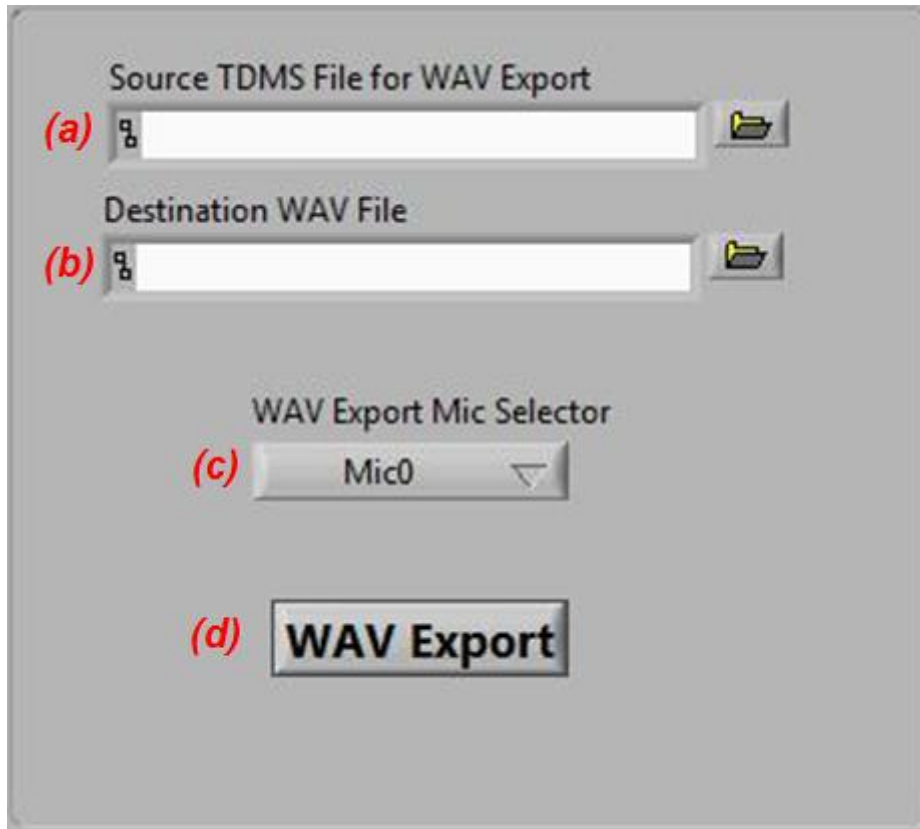


- (f) If the user goes to the directory in which the new Excel file containing the results table is located and opens the file, then the user would find one additional tab located after the four original tabs from the Excel template. As mentioned above, the new worksheet tab label will be “Table.” The data shown in this tab will correlate to the information in the “Stored Results Table” located on the **Test Procedure** main screen in the Labview program.

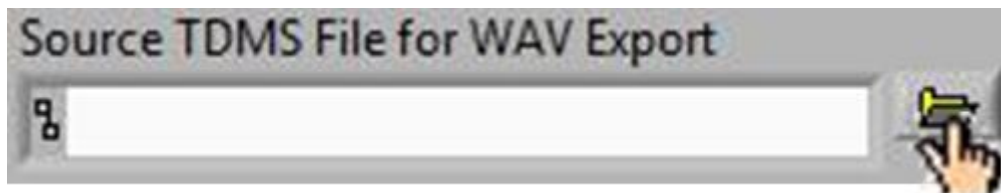
File #	Date	Time	LE OBSI	TE OBSI
1	3/19/201	10:33:13	45.1	46.4
2	3/19/201	10:50:28	45.0	46.0

	A	B	C	D	E	F
1	File #	Date	Time	OBSI - LE	OBSI - TE	
2	1	3/19/2014	10:33:13 A	45.1	46.4	
3	2	3/19/2014	10:50:28 A	45	46	
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						
21						
22						
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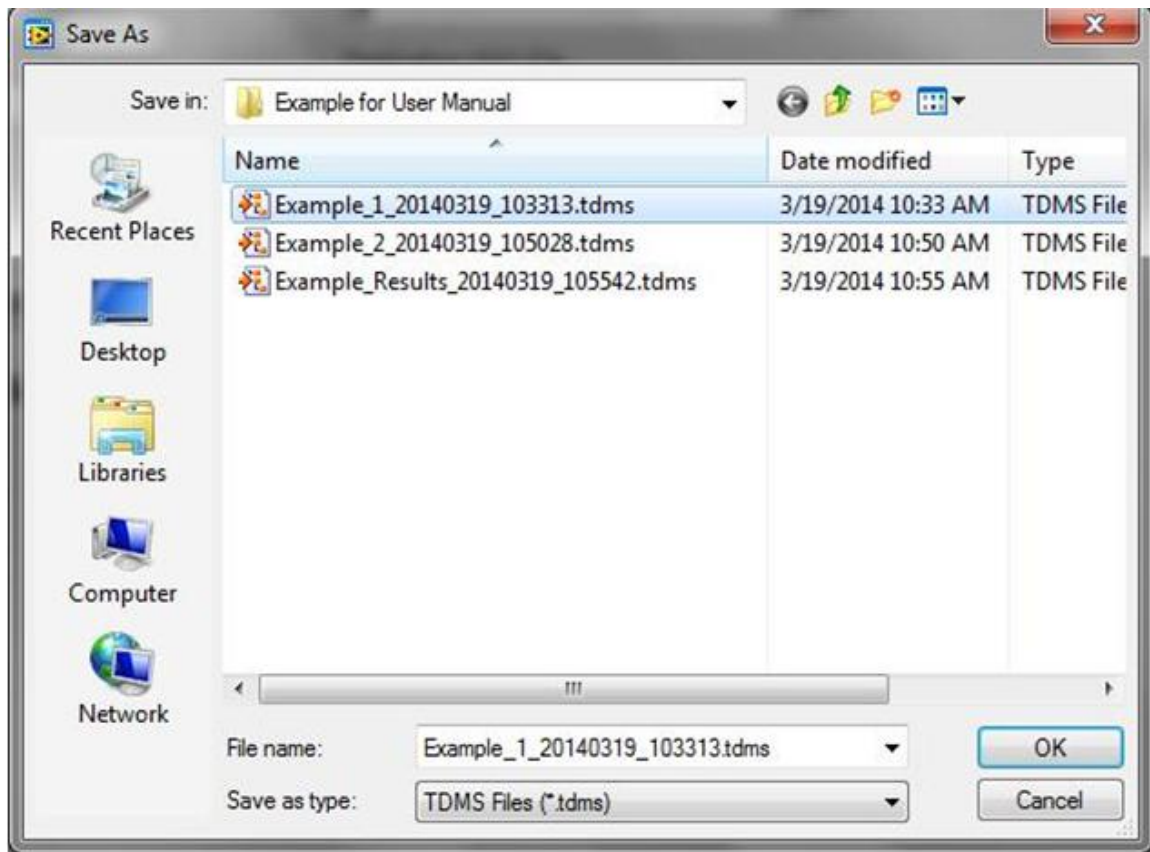
(12) *Data Export to *.wav File* – in addition to exporting the data into tabular form, Labview is also capable of converting data into audible *.wav files. If results from specific runs look “bad” and/or inconsistent, then the user could convert the *.tdms data into *.wav files to listen to the raw signals. Since each run contains results from all four channels, each channel would be converted individually. Listening to each channel, independently, could result in the identification of the source of any “bad” data. This would also benefit in comparing various types of pavement, subjectively.



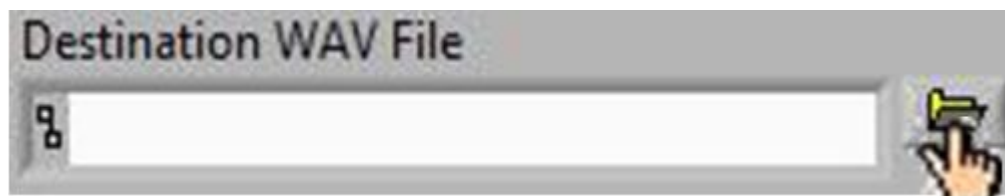
- (a) Source TDMS File for WAV Export – to select the run for which to convert into a *.wav file, first select the open-folder button to right of the empty, white box.



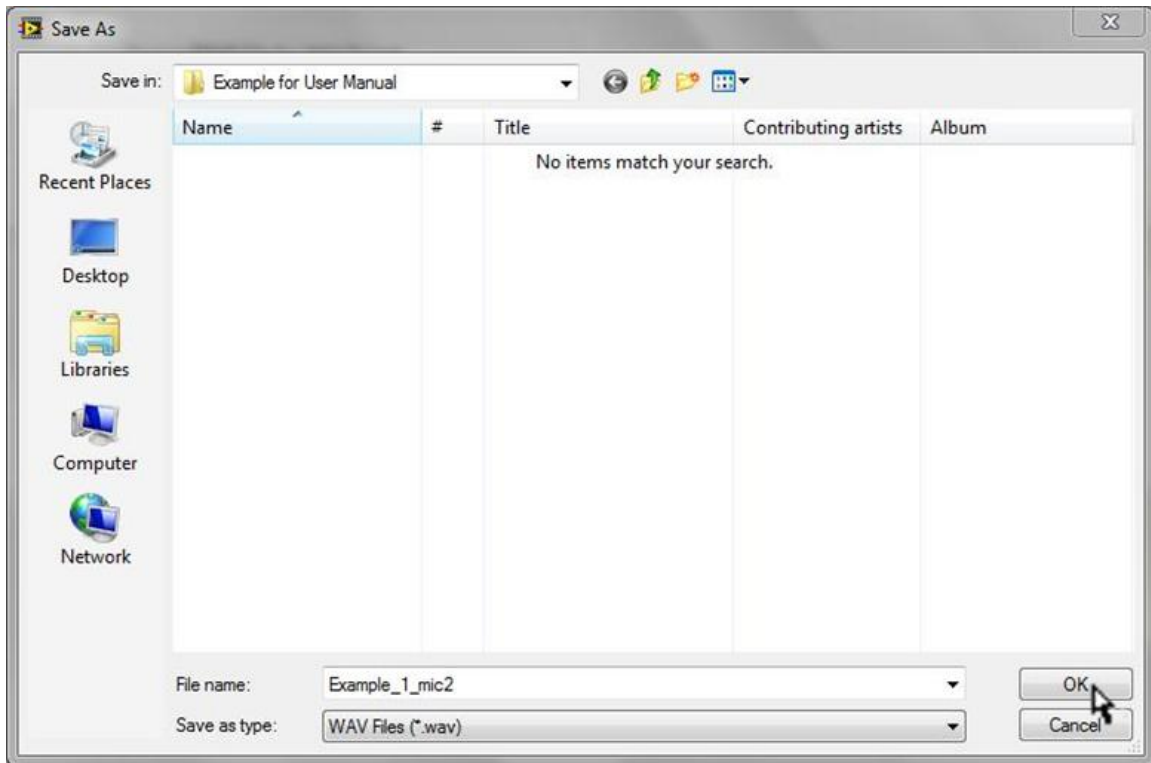
- i) A pop-up window will appear and prompt the user to select the *.tdms file to convert to an audible *.wav file. After the user selects the *.tdms file, hit “OK” to return to the **Data Export** front panel screen.



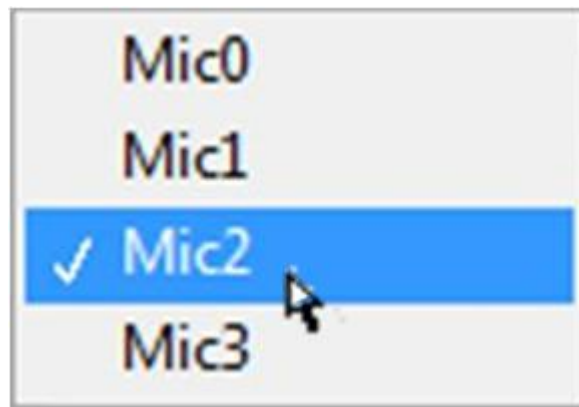
(b) Destination WAV File – to select the name of the *.wav file to be converted and the directory in which the user would like it saved, press the open-folder button to right of the empty, white box.



i) A pop-up window will appear and prompt the user to select the name and directory of the new *.wav file. The “Save as type” extension line should read “WAV Files (*.wav).” When complete, hit “OK” to return to the **Data Export** front panel screen.



- (c) WAV Export Mic Selector – since each *.tdms file contains information for all four channels, the user must select which microphone should be converted to the *.wav file. For this conversion, the user would need to export each channel one at a time. To select the channel, simply click on the drop-down menu labeled “WAV Export Mic Selector,” scroll down to the desired channel name, and click the mouse to select.



- (d) WAV Export – press this button to begin the conversion process (or hit <F11> on the keyboard). The time it takes to create a *.wav file is considerably shorter than the time it takes to export to Excel. So no progress bar would be required.

WAV Export

