

The "ZC v5" Program: A User's Manual for Determining Cycle-to-Cycle Frequencies of Sound Pulses Based on the Zero-Crossing Technique

POWER MACINTOSH VERSION

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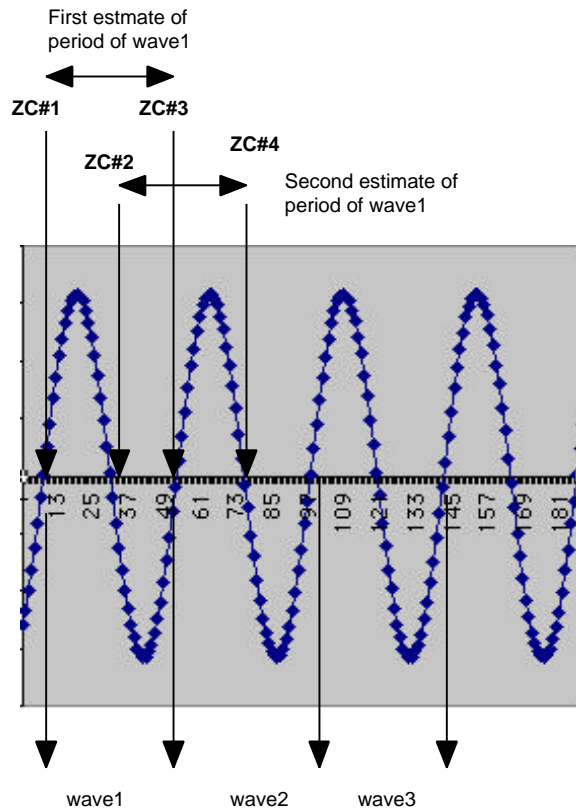
IMPORTANT NOTE: Be sure to keep the files "ZC_v5.lvrt" and "Shared Libraries" in the same folder (as provided) or the program will not work

Features:

- Cycle-to-cycle frequency based on zero crossing.
- Operates on any audio file in text (tab-delimited) format
- Calculates an estimate of rms power for each cycle
- Threshold setting can be used to generate an array of zero crossing values that only includes cycles whose power is greater than a user-set threshold voltage. Threshold is defined relative to the audio signal's peak voltage (pressure). Threshold limits are displayed along with other data on waveform, ZC and power graphs.
- Pre-processing estimation of signal DC . Optional user-controlled removal of DC from the signal (prior to processing).

- Tab-delimited text output compatible with any standard spreadsheet program. Output includes title, sampling rate, threshold used (if any), input signal average AC voltage, DC voltage in absolute terms and as a percentage of the signal peak voltage, and the following data arrays:
 - time and amplitude values for the input signal
 - arrays containing all ZC values and ZC values above the user-set threshold and the times for each ZC event
 - rms "power" for each half cycle as a function of the time of the peak of the cycle.

Description: This program analyzes audio data and calculates frequency on a cycle-to-cycle basis. It arbitrarily starts counting waves with the first point in the record where the microphone voltage or sound pressure crosses zero. Two such crossings later is the start of the second cycle (see lower part of figure on the next page). Thus, the time separating three zero-crossing (ZC) events corresponds to the wave period (see top of figure on next page). Since one cycle has two ZC events, the program calculates the period for both half cycles. This can also be seen in the figure on the next page. These periods are then averaged to give the average period of the wave; the inverse of the average period is the average frequency of this wave. The ZC_v5 program then starts with first zero-crossing event of the next cycle and continues with the process until the frequency of each wave has been measured.

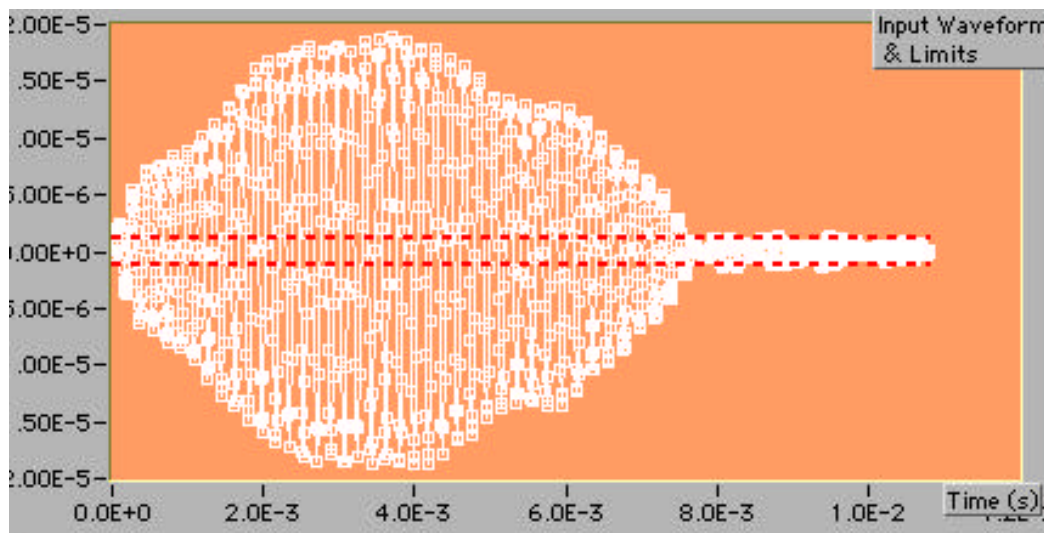


This mechanism might appear unnecessarily complex (why not just measure one average per signal?). It was developed so that half cycle frequencies could be obtained easily and I wanted to give a full description of what the program actually does (but the effect is simply to get the period of each non-overlapping cycle).

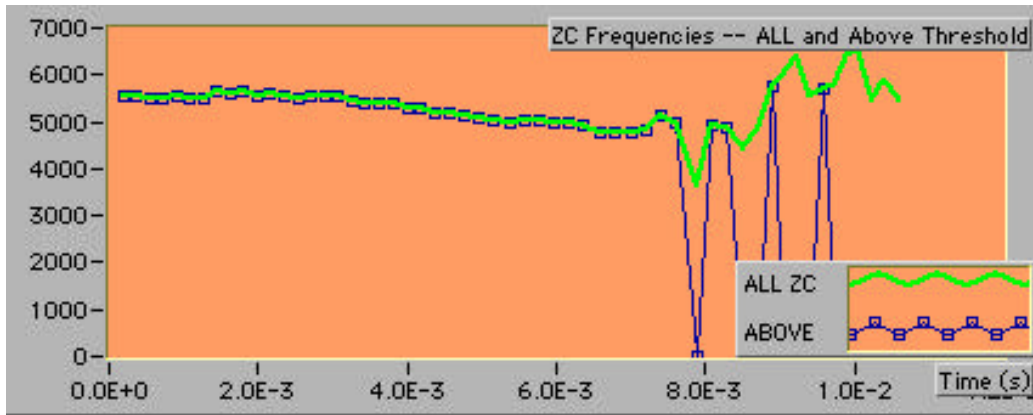
Input Data Format: The ZC_v5 program accepts data only in the form of a tab-delimited text file. Such a file can be readily generated by a number of programs, for example, by Cornell Laboratory of Ornithology's excellent audio analysis program **Canary**. Tab-delimited files generated on spreadsheet programs such as Excel, Matlab, and a number of graphics packages (examples: CricketGraph, DeltaGraph, etc) will also be read **provided that these sheets contain data only (no text)**. ZC_v5 will read data in either column or row formats.

Graphical Displays: The program has three graphical displays:

- the inputted audio waveform is given as some measure of amplitude (e.g., voltage or pressure) vs. time since the start of the sample. The waveform is plotted along with the user-selected **threshold limits** (threshold is defined relative to the peak voltage of a entire inputted signal) which are shown as dotted lines:

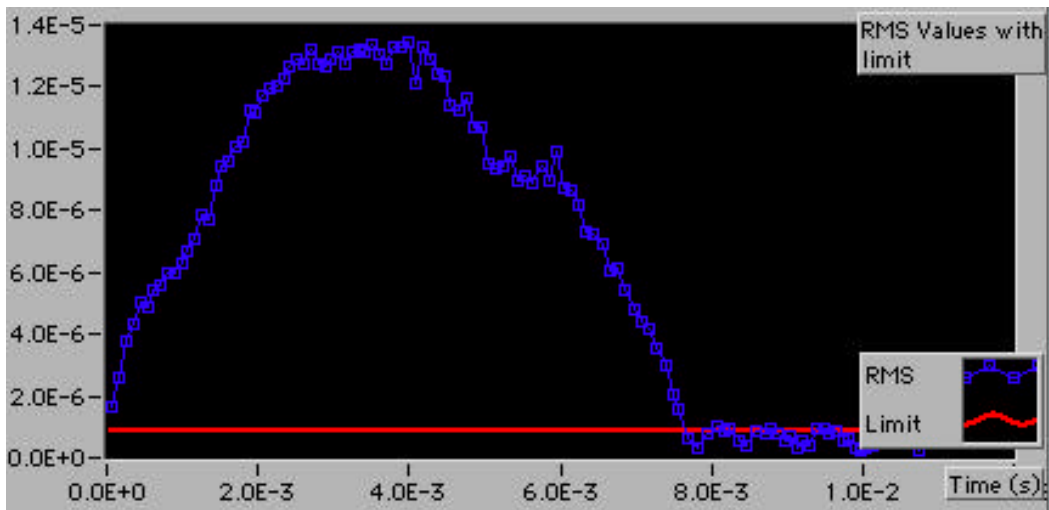


- Two plots of the cycle-to-cycle frequency (**ZC frequency**) -- both versus the time for the ZC events. One array contains all ZC frequencies and the other ignores all cycles where the amplitude was below threshold. Whenever the signal is below threshold, the program arbitrarily defines the ZC frequency as "0".



- A plot of "rms power" of each cycle. Once again the plot also gives a threshold ("Limit") line. Please note that this is not in true power units -- it is voltage squared (see box).

"Power" is calculated using a routine that estimates the rms voltage for each half cycle. At typical carrier frequencies used by crickets and at a typical A/D conversion rate of 44100 this means that each rms value uses about $44,100 / 5000 \text{ Hz} / 2$ (half cycles per cycle) = 4.4 pts per cycle -- for harmonics, this becomes progressively fewer. **If this measure is important to you for frequencies greater than 5 kHz, use a higher effective A/D rate for best results.** In any case, "power" is then obtained by squaring each rms voltage but the resulting value is not divided by impedance and so the result is not in true power units.



Saving Data: The ZC_v5 program immediately saves the waveform amplitude and time data, both ZC arrays (all and above threshold) and the power graph

data along with the settings the program was operated under. The data are saved as a tab-delimited file which can be opened by any program that reads tab-delineated files (such as **Excel**, **Claris** or **Appleworks** or other spreadsheets and graphing programs).

System Requirements: This program requires a Power Macintosh. It has been tested using Mac OS 8.6 and 9.01 but it should run on any system on a Power Mac. Note that **it will not work on 680x0 Macs**. The program itself is a bit of a memory hog. When unstuffed, it requires about 3.3 MB of disk space and when running it prefers 8 MB of RAM.

Required Note: The actual zero-crossing program operates within a run-time engine developed by National Instruments, Inc. (URL: <http://www.ni.com>) ; the two are compiled together.

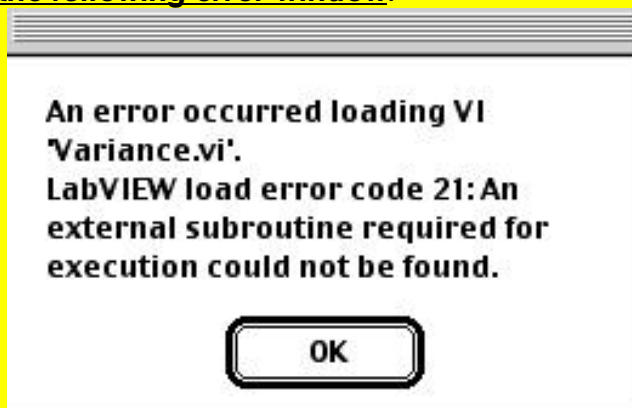
Launching and Setting Up the ZC_v5 Program

1. Launch the program by **double clicking the ZC_V5 .lvrt icon:**



VERY Important Note: Be certain to leave the "ZC_v5.lvrt" icon in the ZC v5 folder along with the file called "Shared Libraries". The program will not operate unless it is in the same directory as the shared libraries directory. I suggest making an alias of the ZC_v5.lvrt icon and placing the alias on your desktop.

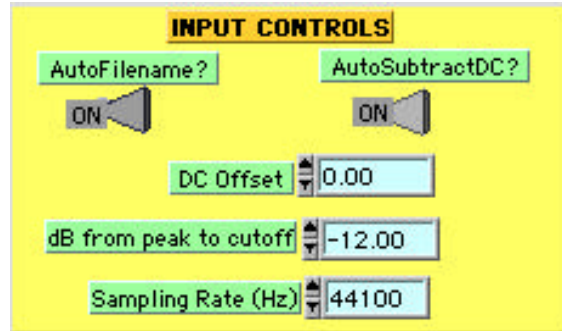
If you ever see the following error window:



you have probably moved the ZC_v5.lvrt program away from the libraries it needs (alternatively, the files have somehow become corrupted and should be replaced).

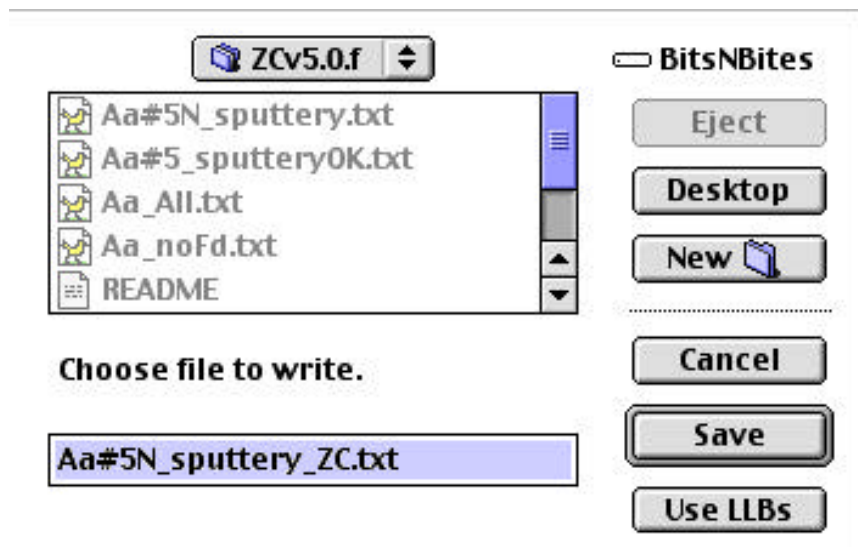
2. The program's **"front panel"** will appear. It is now **important to set a series of parameters that control the ZC_v5 program's calculations and output.**

(a) **Input Controls:** On the upper right of the program's panel is a yellow box marked "Input Controls":



(i) **Auto filename:** This is a new feature. When placed in the "on" position (default) the program will suggest naming the output file based on the name of the input file. It will also append "_ZC.txt" to this filename. It checks to be sure that the filename will not be longer than 31 characters (pre Mac System X limit).

The operation will be clearer using an example. Suppose you turn this feature "ON" and run ZCv5 and load data from a file called **"Aa#5N_sputter.txt"** (we're getting ahead of ourselves here but bear with me). The program will do the computations, display the results and also display a dialog box to save the file:

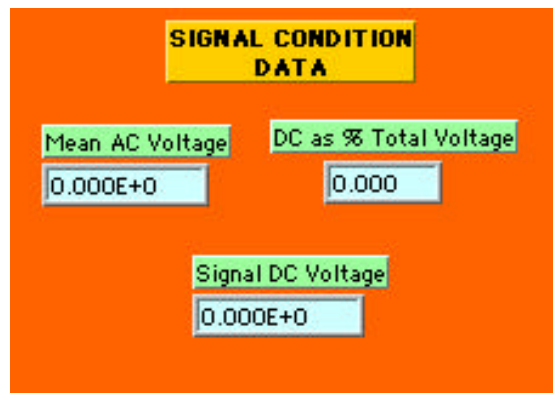


Note that the suggested name is the same as the old except that the extension **.txt has been removed and replaced by "_ZC.txt"**. You may still change the filename if you wish.

If you do not select the autofilename option, the dialog shown above will appear but with no suggested filename.

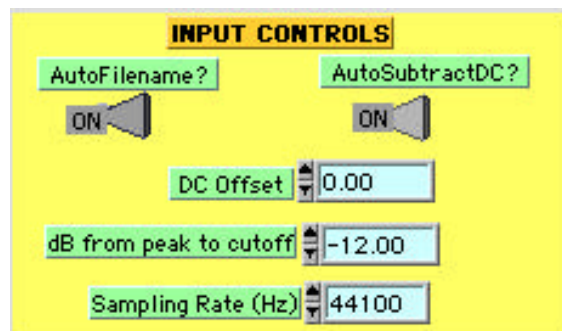
ii. **Autosubtract DC? and DC Offset Voltage:** If DC is present, it will obviously introduce an error by decreasing the ZC period for the portion of the signal with the same sign as the DC offset and increasing the ZC period for the opposite signed values. It also causes the appearance of sideband frequencies related to amplitude modulation of the signal. It should be avoided but it frequently shows up in recordings.

Unlike earlier versions of ZC, v5 will estimate any DC offset when it first begins to process a signal. It will display the value of the DC offset, if any, as a voltage and also as a percentage of the peak voltage found in the signal:



There are two ways to handle any DC that might be present.

The first is to satisfy yourself that the automatic feature works well enough for your purposes. To use this feature (which is the default condition) be sure the "AutoSubtractDC?" switch is "ON" (default) . Don't bother to enter any value for the DC offset (see below) -- if you do, it will not cause any problem because selecting "Autosubtract DC" causes whatever is entered in "DC offset" to be ignored.



So, when you run the program with the "AutoSubtract" feature on, ZC_v5 will estimate the DC and then subtract it from the data points before processing them for ZC and power data. Please note the DC offset values that will be displayed when the program completes running are the values from before the correction was made -- not after. These values (before cleanup) will also be saved on the spread sheet.

Description of the Algorithm for Finding Signal DC and AC Components

Here's National Instrument's Description of their Routine (which I use in ZCv5) for finding DC and AC:

"... if you have a periodic signal and you don't have an integral number of periods in the acquisition, you get spectral spreading, whether or not you're doing an FFT later. This routine performs spectral analysis to the extent that it separates DC (bin 0) from AC (the rms sum of the rest of the bins). It applies the Hann window. This window is sufficient for separating most of the AC energy from the DC bin. The efficient mean and variance computations are used in place of Fourier analysis because the desired results are the total AC energy and the true DC, not information in each individual frequency bin.

The coherent gain and equivalent noise bandwidth constants for the Hann window are needed to compensate for the windowing effects on gain and bandwidth."

(source: Help window, LabView v6, National Instruments, <http://www.ni.com/labview>)

Note: perhaps I'll go to wavelets in the future!

The alternative is to turn the "AutoSubtractDC" OFF and to enter a value for the DC offset. This could be estimated in another program such as Canary. **If you wish no DC correction, simply leave the "DC Offset" control set at 0 (default) and set the "AutoSubtractDC" to OFF.**

How to use the switches:



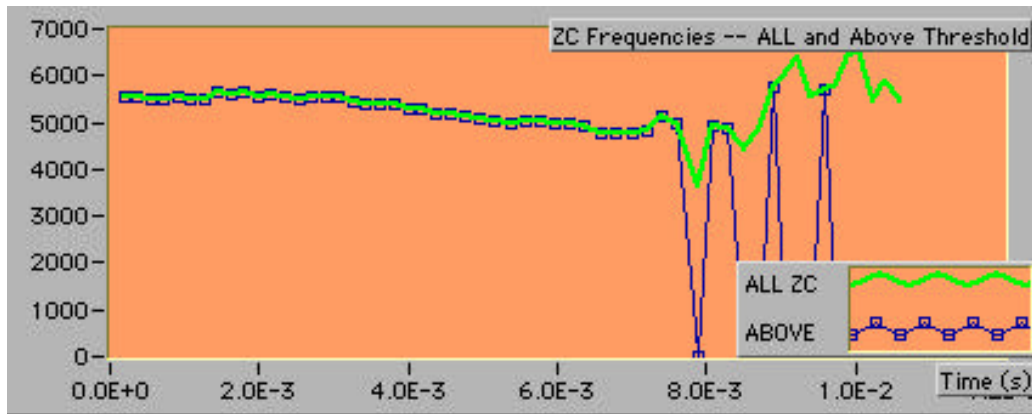
Click to the left of the virtual toggle switch and the switch moves



to the left

vice versa.

Threshold -- dB From Peak to Cutoff: This control will delete the ZC frequencies for all waves whose amplitude is less than a cutoff value. In place of the deleted points, a value of "0" will be entered -- see blue (dark) graph below:



Note that there is no loss of data because the ZC values are still calculated for all points (whether above or below the threshold) and they are present in a separate array which is the green (light) line above and which will also be reported to the output file.

The default threshold is -12dB below the peak voltage of the input waveform (~16X less than the peak).

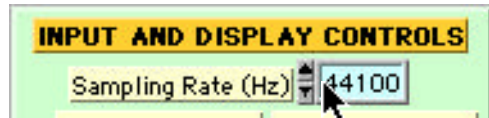
Entering a threshold also causes threshold values to be plotted on the waveform and power graphs (see earlier).

Sampling Rate: Be sure to set the correct sampling rate used to create the digitized audio file. Canary text files do not include this value (at least not where I can find it) and ZC_v5 makes no provision to read them. You must specify it using the Sampling Rate control on the green "Input and Display Controls" panel. The **default is 44,100 Hz**. Instructions are given on the next page as to how to change sampling rate values.

Important note: the best way to increase the frequency resolution of the system to use the highest sampling rate possible. I (knp) generally digitize files at 44100 samples/s using a calibrated tape played at half speed for a realized sampling rate of 88200 Hz. However, for most applications with crickets, 44100 Hz sampling rates will be quite adequate.

Changing Text Field Values: Select and Edit

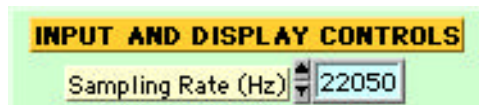
The easiest way to change this setting is to position the cursor in the window where the sampling rate is displayed and click-drag across the window



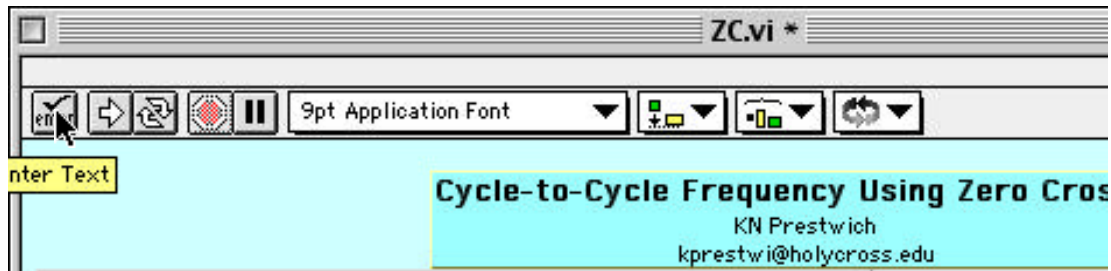
this will result in the window changing color from light blue to light purple:



then simply type in the new value -- for example 22,050 Hz:



and finally click on the "Enter" button that appears at the left of the other icons near the top of the window:



Alternately, simply hit "**return or enter**" on your keyboard. Notice that when you click "Enter" (or hit return) the button will disappear. The "Enter" icon will reappear only when you enter a value in one of the text fields using the selection and editing procedure just described.

Setting "Display" Controls: There will be many occasions where you will want to remove the first or last few points from the ZC graph where artifacts are common. The procedure is to use mouse clicks on the arrows of each text field to adjust the number of points to be deleted. For instance, to delete two points from the end of the record, click twice on the up arrow of "Points to Remove from the End":



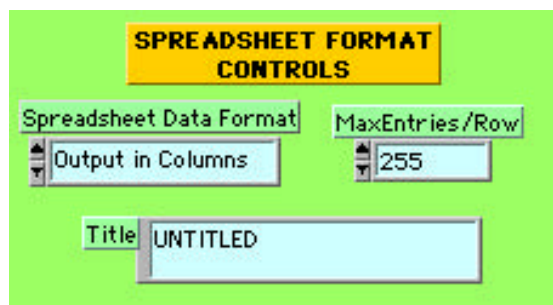
to give:



To view the updated graph, you must run the program again using the arrow icon at the top left. You'll need to call up the same data file as before.

The way this feature is most commonly used is to run the program, don't save the data (see below) and look at the results. Decide how many points to drop and then run it again. Please note that **this is only a tool for visualizing results within ZC_v5 -- all points will be present in the saved data file** (none are deleted from the data file by this procedure).

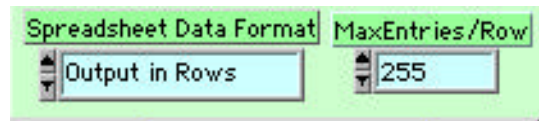
Spreadsheet Format Controls: the next (green) box on the right of the program's window contains controls for the output to the spreadsheet. **As with all controls, these must be set before starting to run the program.** Here is a picture of the controls:



(i) **Title**: This is an optional entry. It prints a title on the first line of the spreadsheet output. Simply select and edit the textfield as described previously for the Sampling Rate control.

(ii) **Row vs. Column Display of Spreadsheet Data**: The ZC_v5 program will read data in either rows or columns. Its normal **default output is to put the data into columns**.

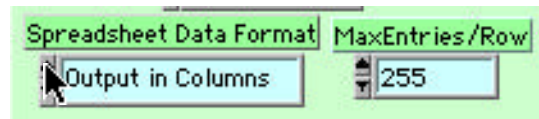
If data are displayed in rows, the maximum number of values in each row can be controlled by the number field to the left of the rows vs. columns control:



The default value is 255 entries, this is one less than the maximum row length permitted by most modern spreadsheets. For most ZC analyses this should be more than enough. However, if you anticipate an output with more than 255 ZC values, the spreadsheet will break the output into one or more rows. This prevents data loss.

Note that this control does not affect column length.

Changes between Row/Column output are made by clicking on the arrow on the left of the "Spreadsheet Data Format" box:



Below is a **sample of the output**:

Here is an example of the top of a row output along with a close up of some of the data:

Name Box		test2											
	A	B	C	D	E	F	G	H	I	J	K	L	
1	TITLE:	UNTITLED	SmpRate:	88200	dBtoCut:	-0.001013	DC_Offst		-12	DCas%	0	ACV	0.00001

	A	B	C
TITLE:	UNTITLED	SmpRate	
WaveformTime			
	1.13E-05	2.27E-05	3.40
	2.90E-03	2.91E-03	2.93
	5.79E-03	5.80E-03	5.82
	8.68E-03	8.70E-03	8.71
DC_CorrectedWaveform			
	-8.12E-07	-6.41E-07	-3.32
	-1.57E-05	-1.10E-05	-4.57
	-3.06E-06	1.52E-06	5.90
	-4.31E-07	-7.78E-07	-1.03
ZC_Cross_Times			
	1.81E-04	3.62E-04	5.44
ZCFreqArray			
	5529.28054	5526.75332	5483.28
>ThreshZCFreqArray			
	5529.28054	5526.75332	5483.28
RMS_Times			
	7.94E-05	1.70E-04	2.61
HalfwaveRMS			
	1.63E-06	2.61E-06	3.78

and the same for columns:

test														
	A	B	C	D	E	F	G	H	I	J	K	L		
1	TITLE:	UNTITLED	SmpRate:	88200	dBtoCut:	-0.001013	DC_Offst		-12	DCas%		0	ACV	0.00001
2	WaveformTime	DC_Corrected	ZC_Cross_Tin	ZCFreqArray	>ThreshZCFre	RMS_Times	HalfwaveRMS							
3	1.13E-05	-8.12E-07	1.81E-04	5.53E+03	5.53E+03	7.94E-05	1.63E-06							
4	2.27E-05	-6.41E-07	3.62E-04	5.53E+03	5.53E+03	1.70E-04	2.61E-06							
5	3.40E-05	-3.32E-07	5.44E-04	5.48E+03	5.48E+03	2.61E-04	3.78E-06							
6	4.54E-05	8.92E-08	7.27E-04	5.47E+03	5.47E+03	3.51E-04	4.34E-06							
7	5.67E-05	6.69E-07	9.08E-04	5.54E+03	5.54E+03	4.42E-04	5.07E-06							
8	6.80E-05	1.36E-06	1.09E-03	5.49E+03	5.49E+03	5.33E-04	4.91E-06							

and

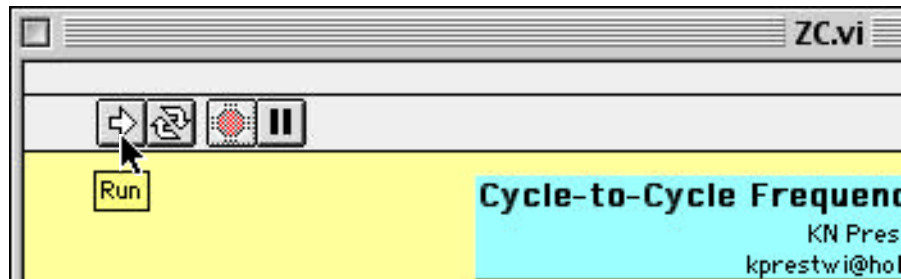
A	B	C	D	E	F	G
TITLE:	UNTITLED	SmpRate:	88200	dBtoCut:	-0.001013	DC_Offst
WaveformTime	DC_Corrected	ZC_Cross_Tin	ZCFreqArray	>ThreshZCFre	RMS_Times	HalfwaveRMS
1.13E-05	-8.12E-07	1.81E-04	5.53E+03	5.53E+03	7.94E-05	1.63E-06
2.27E-05	-6.41E-07	3.62E-04	5.53E+03	5.53E+03	1.70E-04	2.61E-06

Running the ZC v5 Program

If you are not familiar with programs developed using National Instrument's LabView environment, please realize that they are somewhat different from other programs and may take some getting used to! The biggest difference is that double clicking the icon (see earlier) causes the programs controls to appear but does not really run the program. Instead, as just described, you set a series of parameters and then push an icon to run the program. The program itself is reasonably nimble but each time it runs it will force you to tell it what file to open and then it will ask you where to save it -- all before you get to look at the data. But you can skip the save step and then look at the data and if you like what you see, run the program again and this time save the results. It is very fast and so this weird behavior is a minor inconvenience. OK, here goes:

push the **forward**  **(run) arrow**

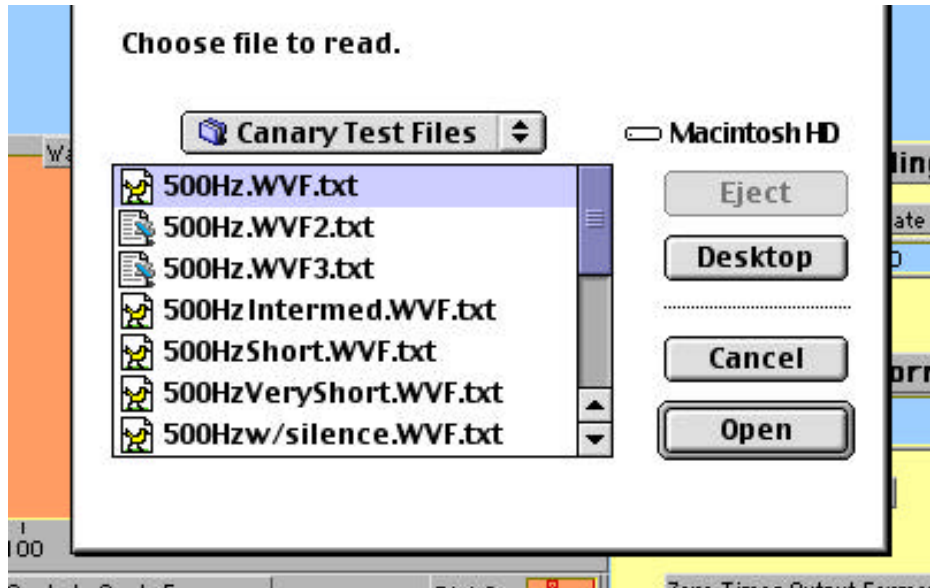
in the **upper left** of the window:



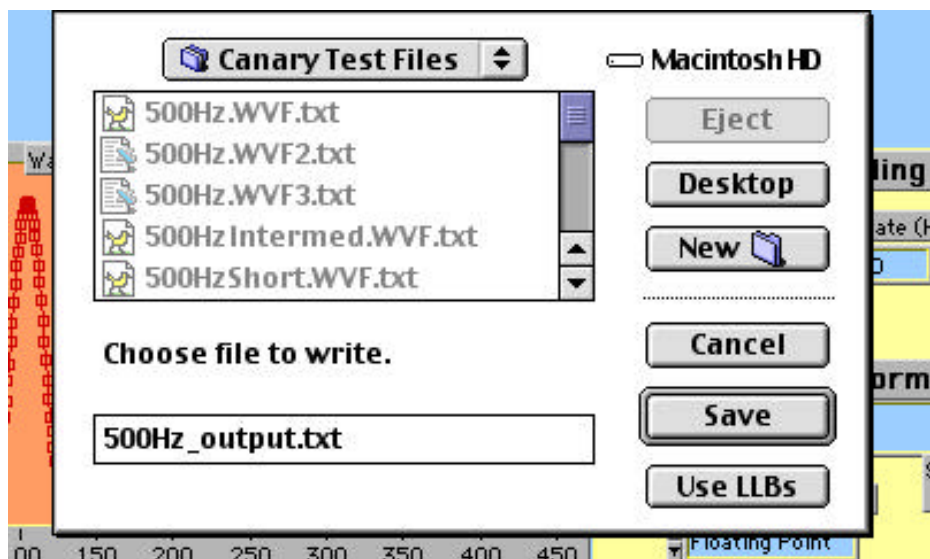
As soon as this is done, the arrow icon changes:



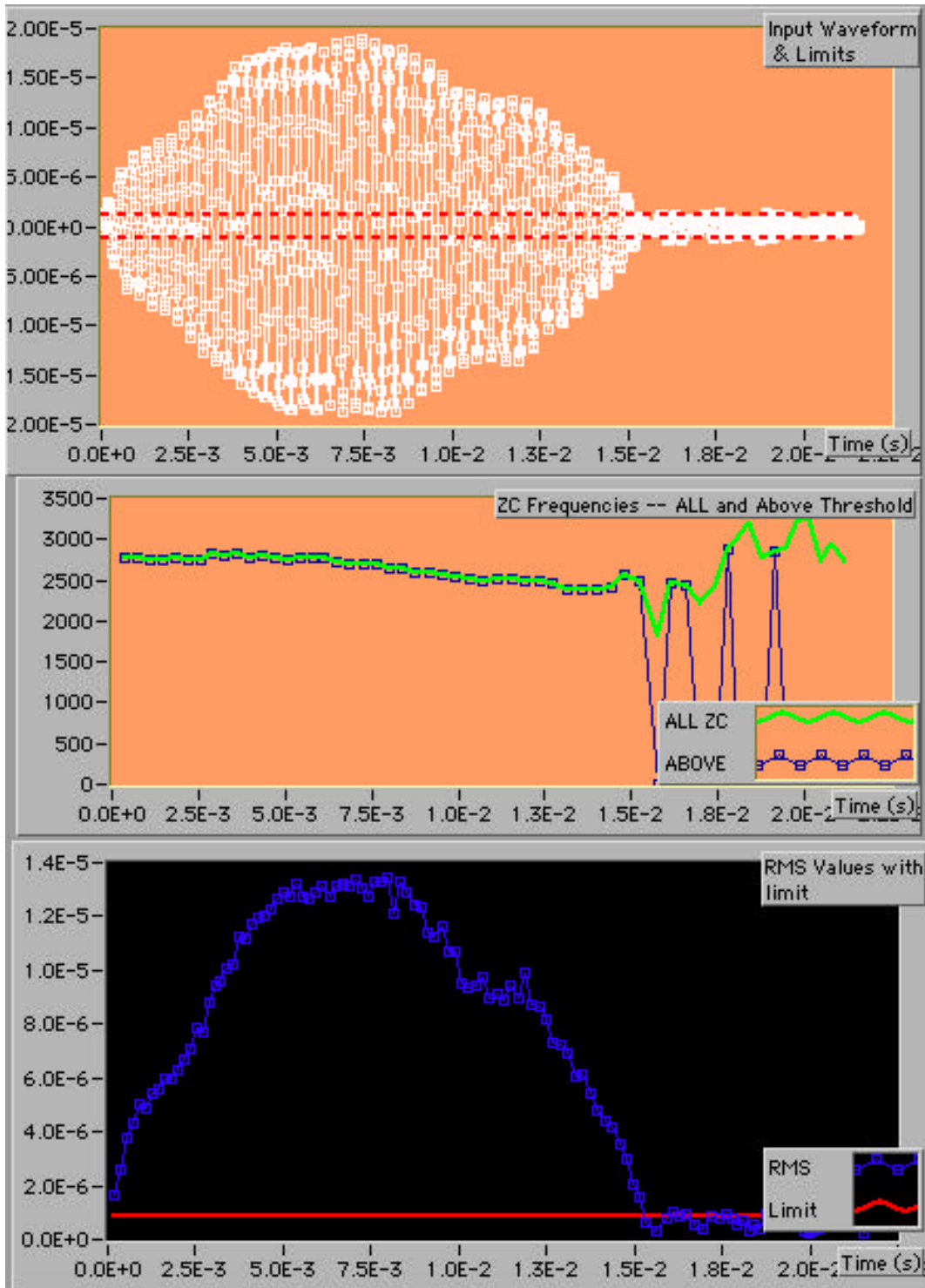
A dialog box appears asking for the name of the textfile containing the audio data:



Navigate to the file you want following the usual conventions. After selecting and opening the file, the dialog box disappears, graphs appear in the background, and then the "Save Output" dialog box immediately appears. It suggests a filename according to the options you selected from "Input Controls" before you ran the program (in this example I have turned off "AutoFileName?"):



After choosing a directory and entering a file name and clicking "Save", this dialog box disappears and the graphs can be viewed (see next page):



About the Graphs: The graph axes are set automatically. Often, especially with the ZC frequency data, extreme points at the start or end of the record can make variation in the main part of the record very difficult to see. This is evident in the outputs for a 500 Hz signal pictured above -- two points near zero at the end of the data set obscure variation in the main part of the data set.

As was mentioned above -- to remove extreme points from the start or finish of a record, (the only place where they are likely to be true artifacts), the procedure is to use mouse clicks on the arrows of each text field to adjust the number of points to be deleted. For instance, to delete two points from the end of the record, click twice on the up arrow of "Points to Remove from the End":



to give:

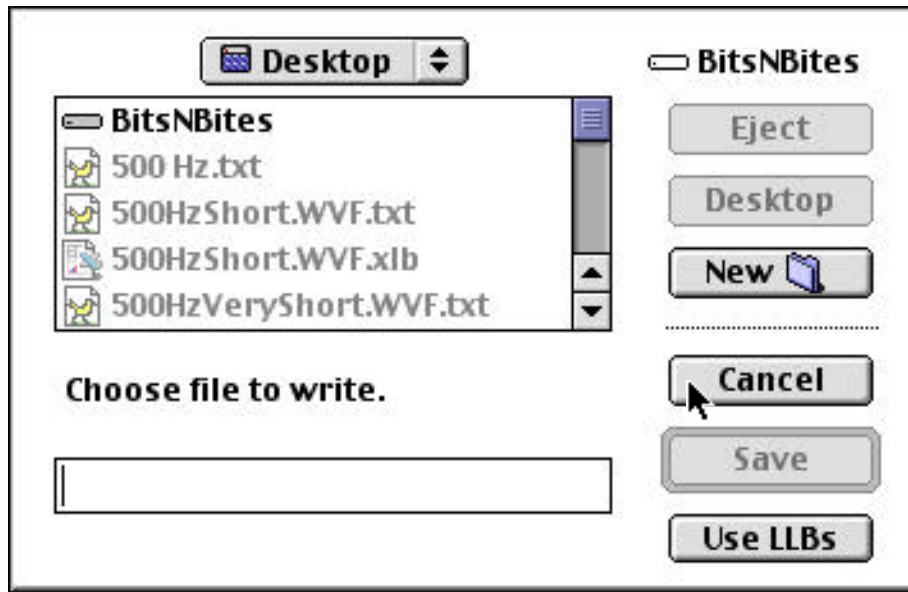


To view the updated graph, you must run the program again using the arrow icon at the top left. You'll need to call up the same data file as before.

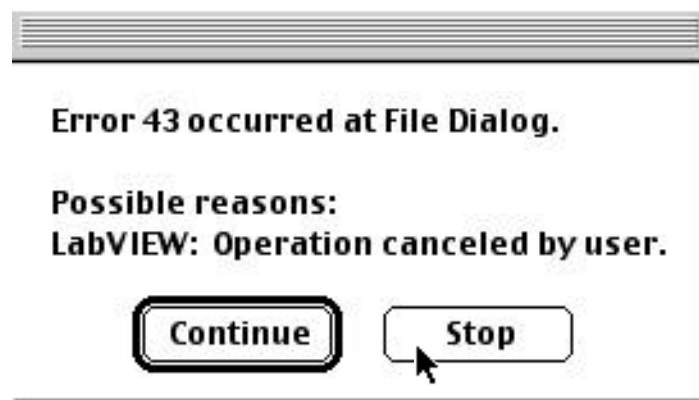
Important Note: this procedure will not delete these values from the spreadsheet data output. You will need to remove them from the spreadsheet yourself. The purpose of this feature is just to get a quick preview of the data without going to the spreadsheet.

General Information About the Program can also be accessed by pressing "command-I".

How to Cancel Saving Data to a Spreadsheet. Suppose that you simply want to look at some data and not save it. This is easy, if a bit un-nerving. When the "Save" dialog box appears automatically when the program is run, hit **"CANCEL"** or press the **escape** key.



A highly intimidating "Error" dialog will appear immediately:



Press "Stop" or "Continue" and all this nonsense will end with no harm done.

Spreadsheet Output: Opening with Excel: If you open the file from within Excel, you may get a text box such as this:



Simply accept whatever it is telling you by immediately punching "Finish" and you're ready to go.

Alternately, **you can drag the file to your Excel icon and drop it.** The file will open without the dialog box shown above.

About Doing Additional "Saves": Because of the way that LabView runtime instruments work, doing additional saves without having to re-open the original data file is not an option. Given the speed with which ZC_v5 executes, hopefully it will not be too large an inconvenience to simply run the entire program a second time.

Acknowledgements, Disclaimer, and Statement of Free Use

Acknowledgements: Professor Henry Bennet-Clark gave many excellent suggestions to me during the development of this program. These suggestions, I believe, very substantially improved the final program. Henry also tested the program extensively. I wish to thank him for all of his assistance and encouragement in its development.

I want to express my thanks to the College of the Holy Cross for support in the development of the program.

Disclaimer: Any glitches or imperfections that may still lurk in the program are solely my responsibility.

Terms of Free Use: The ZC_v5 program is not to be sold. It may be obtained free from the author (email: kprestwi@holycross.edu) and may be bundled with commercial software if permission is first obtained from the author.