**Experiment 12: Calibrating A Sound Card Oscilloscope**

Developers   RB Lineberry, RF Cooper, WC Headley, WD Shumate, RW Hendricks, C Shek, K Meehan

Objective   The objective of this experiment is to build and calibrate two input ports for a Zeitnitz dual-trace sound card oscilloscope that will behave as physical 1x and 10x inputs and will provide calibrated voltages that may be read from the oscilloscope screen.

Estimated Time for Completion
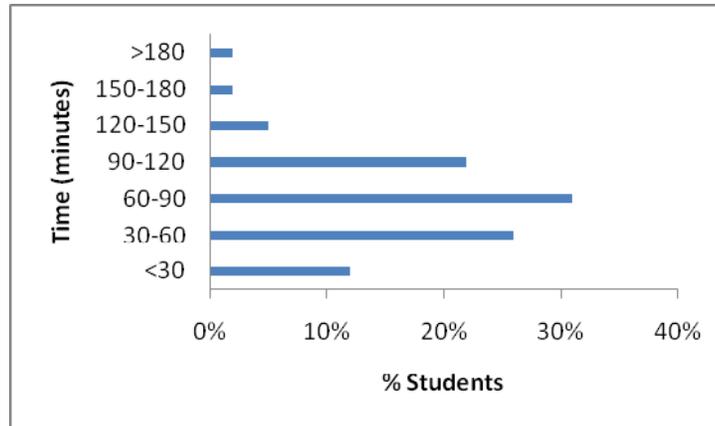
Preparation   If you are not familiar with the features and operation of an oscilloscope, read the excellent tutorial provided by Tektronix (2001). Read Section 2.6 of this manual, which describes the Zeitnitz sound card oscilloscope and the Zeitnitz installation manual (Zeitnitz 2008a). The Behringer UCA202 (Behringer) manual can be obtained through www.behringer.com with valuable support information.

      Note: This experiment does not need to be performed if you are using either a USB oscilloscope such as the ones from Parallax, Pico Technology, or USB Instruments, or any true hardware oscilloscope.

Background   Low-cost software oscilloscopes that interface to the physical world via a PC sound card must be calibrated if one is to make accurate voltage measurements from the oscilloscope screen because of the unknown gain of the sound card hardware. A complicating factor results from the change in gain, which is an outcome from changes in the volume setting of the sound card. Another consideration is the maximum voltage that may be applied to a sound card input before it becomes non-linear or perhaps even saturates. Our experience has shown that the maximum voltage that should be applied to the input of the UCA202 sound card is 0.9 volts, peak-to-peak.

      The probes for "real" oscilloscopes usually have both 1x and 10x attenuators built-in. These probes are designed to reduce (attenuate) the input signal to values small enough so that they do not saturate the front-end electronics of the oscilloscope. There are no such attenuators available to purchase for a software oscilloscope that uses a sound card as the front end. Thus, if one expects signals above 1 V, then it is necessary to build (and calibrate) 1x and 10x attenuators to which the sound card inputs will be

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attached. Then, the node of the circuit to be measured may be connected to the attenuator. As an added complication, real oscilloscope probes have very high input impedances (> 1 MΩ). The simplest possible attenuator is a voltage divider network. But, such networks generally have low input impedances and will thus load the network under test. To alleviate this problem, a non-inverting op amp will be installed to buffer the input signals and provide the necessary high input impedance to the attenuator network.

The calibration procedure consists of the following steps:

1. Determine the gain of the hardware at a fixed, and reproducible, volume level of the sound card.
2. Design a circuit that simultaneously provides for both the 1x and 10x inputs, but provides an input impedance of > 1 MΩ.
3. Build the network in such a way that it may be kept permanently on the breadboard and be available for use in many different experiments.

The recommended hardware and software for the Lab-in-a-Box consists of a Behringer UCA202 external USB sound card as the interface between the ANDY board and a software oscilloscope provided by Christian Zeitnitz of the Johannes Gutenburg-Universität Mainz (Zeitnitz 2008b). After installing the Zeitnitz software and setting the software volume gain to its maximum value, a precision voltage source was used to determine that this hardware/software combination had a gain of 2.18. A true voltage of 1.00 V on the ANDY board, as generated by the known source, produces a signal with a reading of 2.18 V on the oscilloscope screen. Thus, the input signal must be attenuated. To easily incorporate both the 1x and 10x ranges in the circuit, we design a circuit as shown in Figure 1. After calculating the resistor values, some minor adjustments were necessary to produce the desired system gain. In particular, higher resistor values interacted with the UCA202. Note the combination of resistors has been selected so that every resistor needed is available in the standard resistor kit (See Appendix A). If a different sound card is used, it will be necessary to measure the gain for that system and adjust the voltage divider networks accordingly.
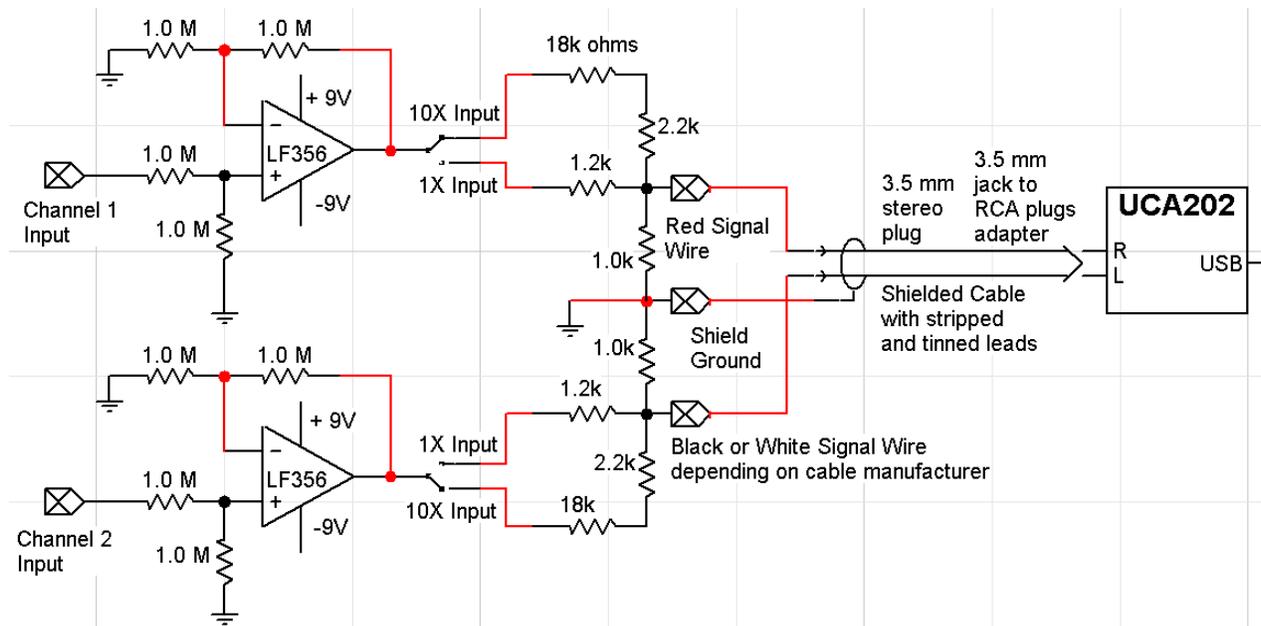
Figure 1: Block Diagram of 1x and 10x attenuator resistor networks.

References   Tektronix Inc. (2001). XYZs of Oscilloscopes.
(search http://www.tek.com/ for "XYZs of Oscilloscopes")

Zeitnitz, C. (2008a). Manual for the Sound Card Oscilloscope V1.24
(http://zeitnitz.de/Christian/Scope/Scope_en.html)

Zeitnitz, C. (2008b). (http://zeitnitz.de/Christian/Scope/Scope_en.html)

Behringer (http://www.behringer.com)

Materials and Supplies   The parts and components required to perform this calibration are:

- 1 ea "ANDY" board
- Breadboard wire and strippers
- 1 ea Behringer UCA202 USB sound card or equivalent, with stereo line input
- 1 ea adapter, 3.5mm stereo jack to 2 RCA plugs
- 1 ea stereo shielded cable, 3.5 mm plug to stripped-and-tinned leads
- 1 ea Zeitnitz oscilloscope software. Download the Zeitnitz software from the text WWW site found at (http://www.wiley.com/college/Hendricks)
- 8 ea 1 MΩ resistors
- 2 ea 18 kΩ resistors
- 2 ea 2.2 kΩ resistors
- 2 ea 1.2 kΩ resistors
- 2 ea 1.0 kΩ resistors
- 2 ea LF356 op amps
- 2 SPDT slide switch, compatible with breadboard sockets
- 1 ea RSR MY-64 Multimeter or equivalent to measure RMS AC volts at 60 Hz.

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You **must** have a fresh alkaline battery in your meter to accurately calibrate your circuit.

Procedure   **UCA202 Installation:**

1. Insert the UCA202 USB cable into one of your computer's USB jacks.

2. If you are running MS Windows XP or Vista, the computer should immediately recognize the hardware as a sound card by showing pop-ups indicating "Sound, Video, Game Controllers – USB Audio Device." Other Windows operating systems may give different messages. See the Behringer support page for additional instructions (Behringer).

Zeitnitz Software Installation:

1. Download the Zeitnitz software from the text web page (see Materials and Supplies) into an empty, temporary folder.

2. Unzip the downloaded file and run "setup.exe" (right-click and "Run as administrator" when installing in Microsoft Vista).

3. When the installation is finished, you may delete the temporary folder and then open the program. The program can be found under the Start menu by going to "All Programs -> Scope -> Scope."

4. When the program has been opened and you have pressed Close at the disclaimer screen, go to the "Extras" tab and make sure that under the heading "Audio Devices" the input indicates "USB Audio CODEC." If it does not, see the Zeitnitz User Manual (Zeitnitz 2008a) for details on making this connection.

5. While still in the "Extras" tab, click on the "Input" button that can be found under the heading "Open Audio Mixer." This will open the "Sound" window.

6. While in the "Recording" tab, click the "Microphone" with the "USB Audio CODEC" as the subtitle. Afterwards click the "Properties" button located at the bottom right corner to open the "Microphone Properties" window.

7. While in the "Microphone Properties" window, click on the "Levels" tab and move the slider to 100% and click OK. (Note: **Do not** change this setting once the calibration is completed.)

8. Choose the "Advanced" tab and for "Default Format," select "2 channel, 16 bit, 44100 Hz (CD Quality)". OK to close all sound properties windows.

9. Sometimes, the "Trigger" indicator will stop flashing, even though the other controls seem to function. Rotate the "Time" knob, until the trigger indicator begins to flash. Then re-adjust the "Time" control.

Initial Calibration of the Attenuator Circuit:

1. Build the circuit shown in Figure 1 in the upper right hand corner of the ANDY board. A photo of one such implementation is shown in Figure 2. It is convenient to build the Channel 1 attenuator with green wires and the Channel

2 attenuator with red wires as shown in Figure 2, thus making the color coding match the colors of the traces shown on the oscilloscope screen. Note that Channel 1 has been built to the left of Channel 2 to make it easier to remember which channel is which. **Remember** to connect the ANDY power supplies and ground to the breadboard busses.

2. Attach the stereo cable to the resistor divider network, plugging the stripped and tinned leads into the breadboard as indicated in Figures 1 and 2. Note that the larger, black wire is the ground, while the smaller red wire is Channel 1 and the smaller black wire is Channel 2. If your cables have a different color code, experimentally determine which color wire corresponds to which Channel. Note that the UCA202 inputs are RCA jacks, so we need a "3.5mm stereo jack to 2 RCA plugs" adapter (see Figure 3).

(a) For each Channel's attenuator circuit, sliding a switch lever to its left position (shown in Figure 2) provides 1x attenuation and sliding it to the right position gives 10x attenuation.
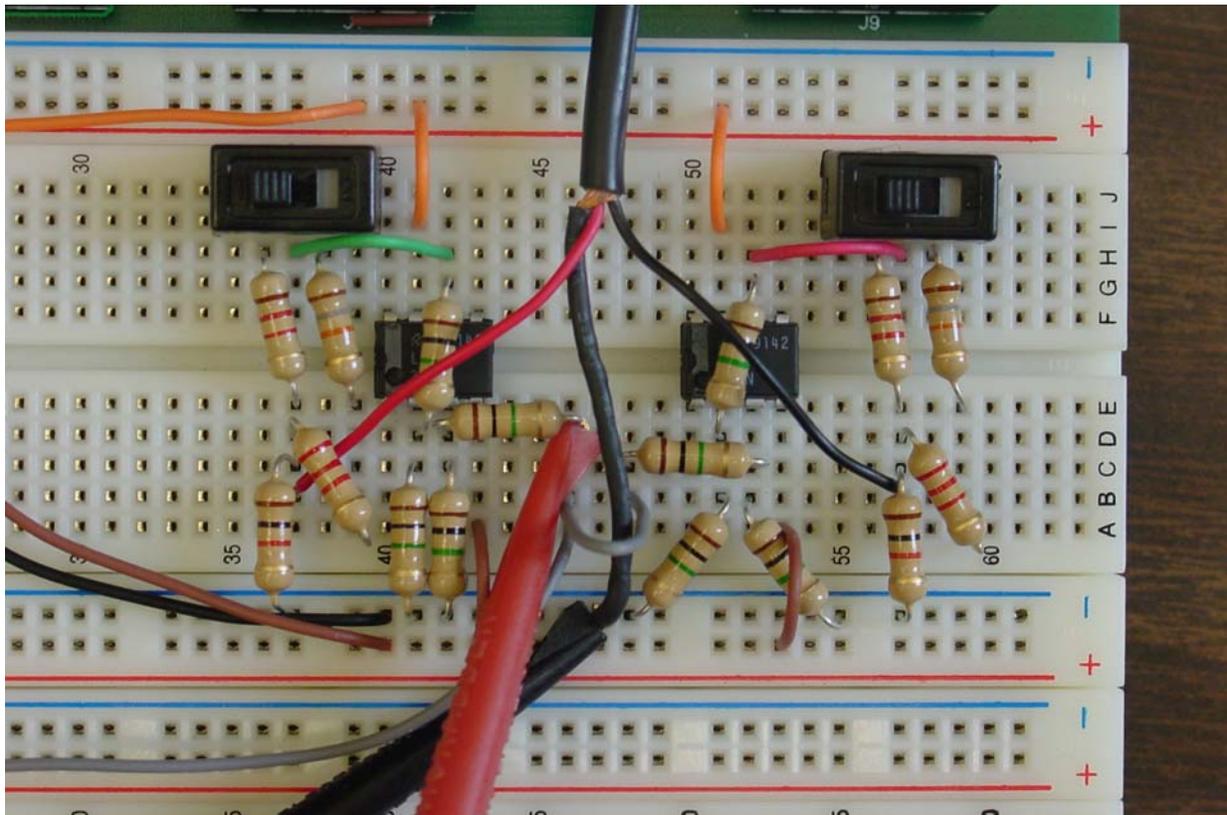

Figure 2: Implementation of attenuator circuit on the ANDY board.

3. Insert the stereo cable plug into the RCA adapter jack. Insert the RCA plugs into the UCA202 "L" and "R" input jacks (see Figure 3).

4. Connect the two attenuator inputs together, as shown in Figure 2.

5. Set both sets of attenuator circuit jumpers for 1x. Refer to 2(a), above.

6. Connect a wire from the ANDY board GEN output to the attenuator inputs. The GEN circuit shares a common ground with the attenuator circuit.

Figure 3: Connecting cables to the UCA202

7. Adjust the function generator on the ANDY board as follows:

   - AMPLITUDE, FREQ and FINE FRQ controls fully counterclockwise
   - SHAPE switch in the SIN position
   - OFFSET SW set to OFF

8. Apply power to the ANDY board.

9. Connect the RSR MY-64 multimeter (in the 2 V ~ [AC] position) to each attenuator input and ground (see Figure 2), and adjust the ANDY GEN AMPLITUDE trimpot until the attenuator input is between 0.740 and 0.745 volts RMS. Adjust the ANDY AMPLITUDE trimpot, and remove your fingers before measuring, to avoid disturbing the trimpot setting. Record this value for future calculations.

10. Using the RSR MY-64 multimeter, measure the output of each of the LF356 op-amps (pin 6), to insure that the output voltage equals the voltage at the input resistor (each op-amp circuit has a gain of 1.0). There may be a slight variation, due to component tolerances.

11. Return to the Zeitnitz Soundcard Oscilloscope window and go to the "Oscilloscope" tab.

12. Move the "Time [msec] knob to obtain a range of 20 ms in the oscilloscope window. You may also type in "20 <enter>" in the text box located directly below the knob.

13. Move the "Amplitude" knob to obtain a range of 0.1V / Div in the oscilloscope window. You may also type ".1 <enter>" in the text box located directly below the knob.

14. Set the Channel 2 attenuator to 1x and set the left attenuator for 10x (Refer to 2(a), above). The resulting waveform, displayed in the Zeitnitz Oscilloscope tab, should look like figure 4. If your waveform is not similar, check your circuit for wiring errors and retrace your steps in this experiment. If you still can't find the problem, consult with your teaching assistant or instructor.
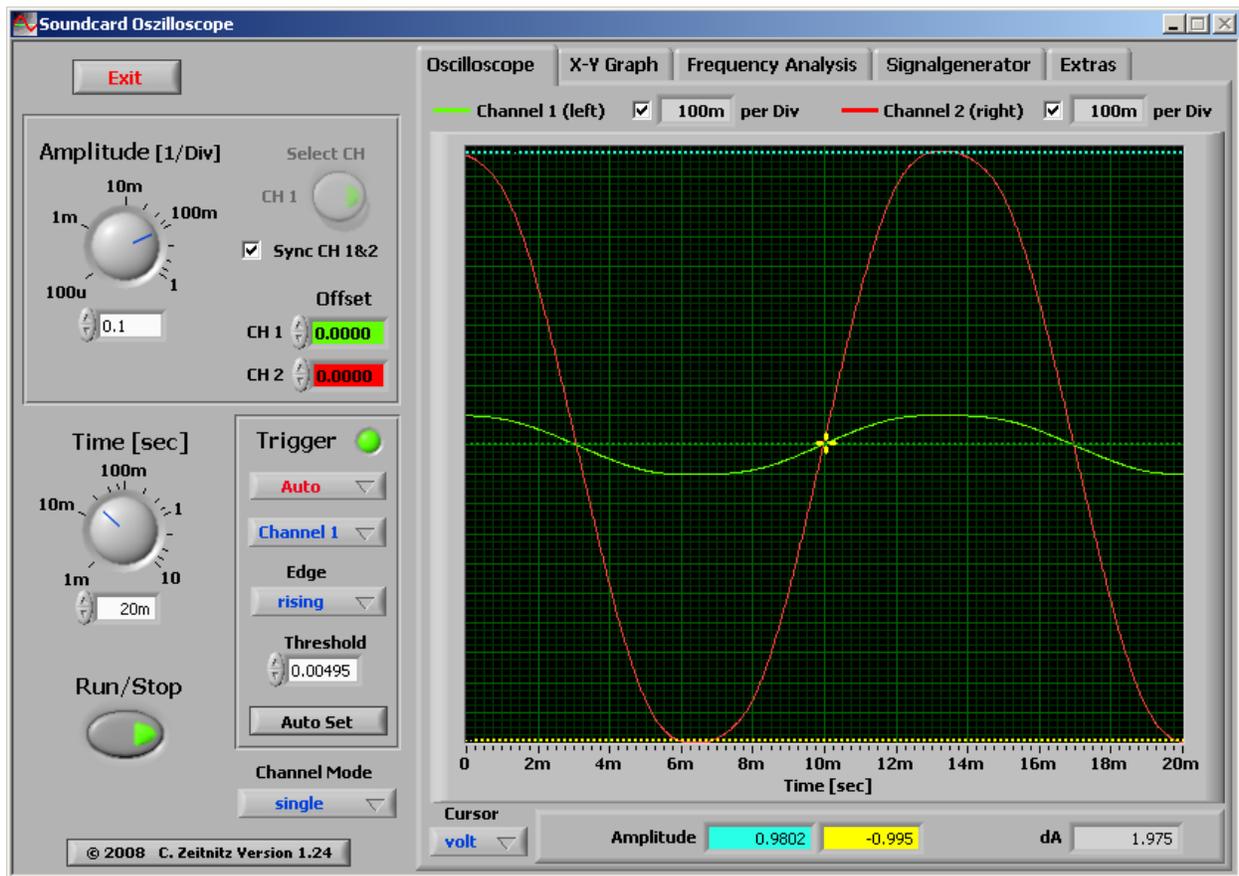

Figure 4: Initial calibration waveform

15. Change the left attenuator to 1x and the right attenuator to 10x. The resultant waveform should look like Figure 5.
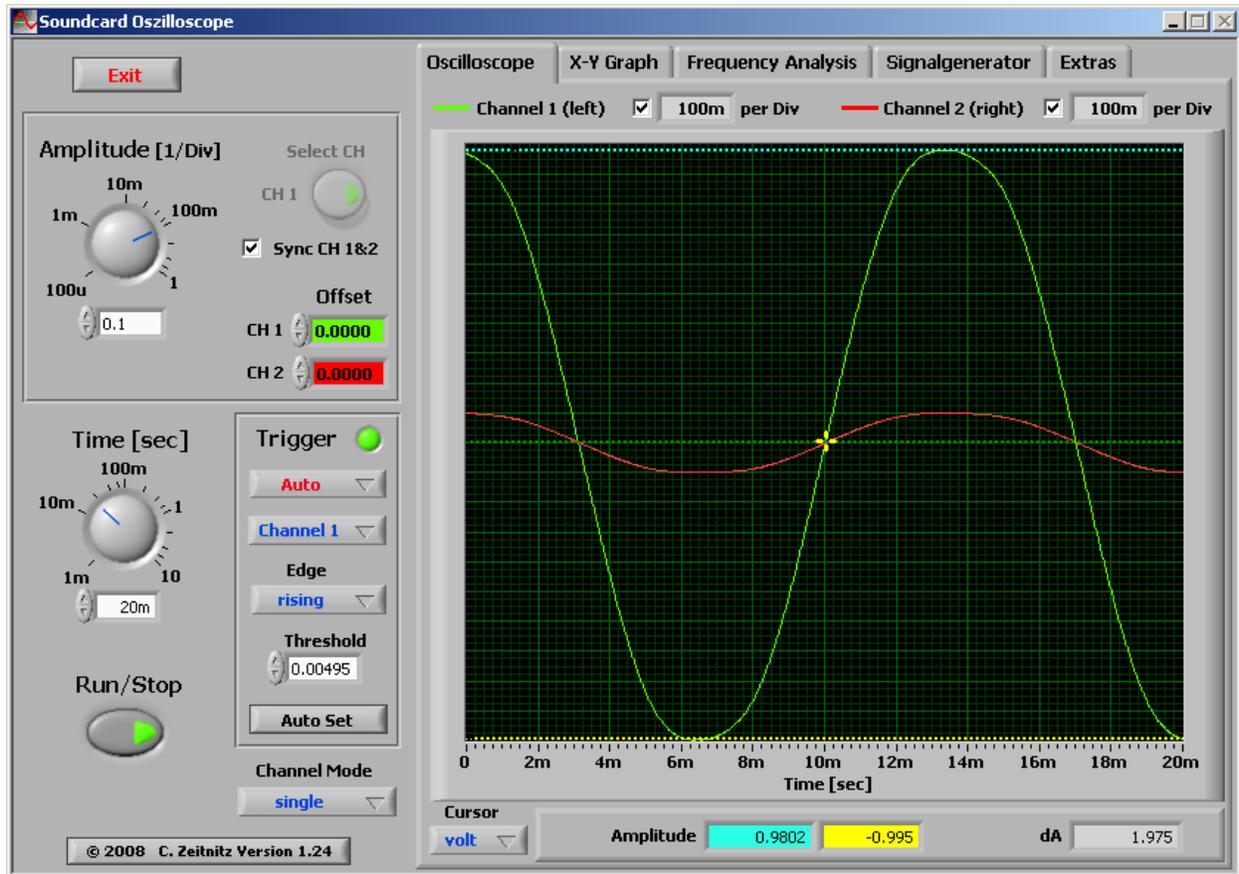
Figure 5: Using voltage cursors to display peak-to-peak voltage.

16. In the Zeitnitz window, set Cursor to "volt." Using the left mouse button drag the upper cursor to the top of the larger waveform. Drag the lower cursor to the bottom of the larger waveform. See Figure 5. The "Amplitude" windows show the values of each cursor and the "dA" window shows the difference between the cursors' values. In this example, the MY-64 measured 0.741 volts RMS, at the op-amp output, and the "attenuator+UCA202+Zeitnitz" combination indicates 1.975 volts peak-to-peak. We would expect to see (0.741)*(2.8[P-P conversion]) = 2.10, so we have an error of 5%, which is reasonable, given component and human errors.

17. Change the Cursor setting to "time." Adjust the cursors to measure one complete period. Using the zero crossings is convenient. In this example, shown in Figure 6, dT (delta time) is 13.909 ms and f (frequency) is 71.893 Hz. Each ANDY board will have component variations, which will affect the lowest frequency produced by the function generator.
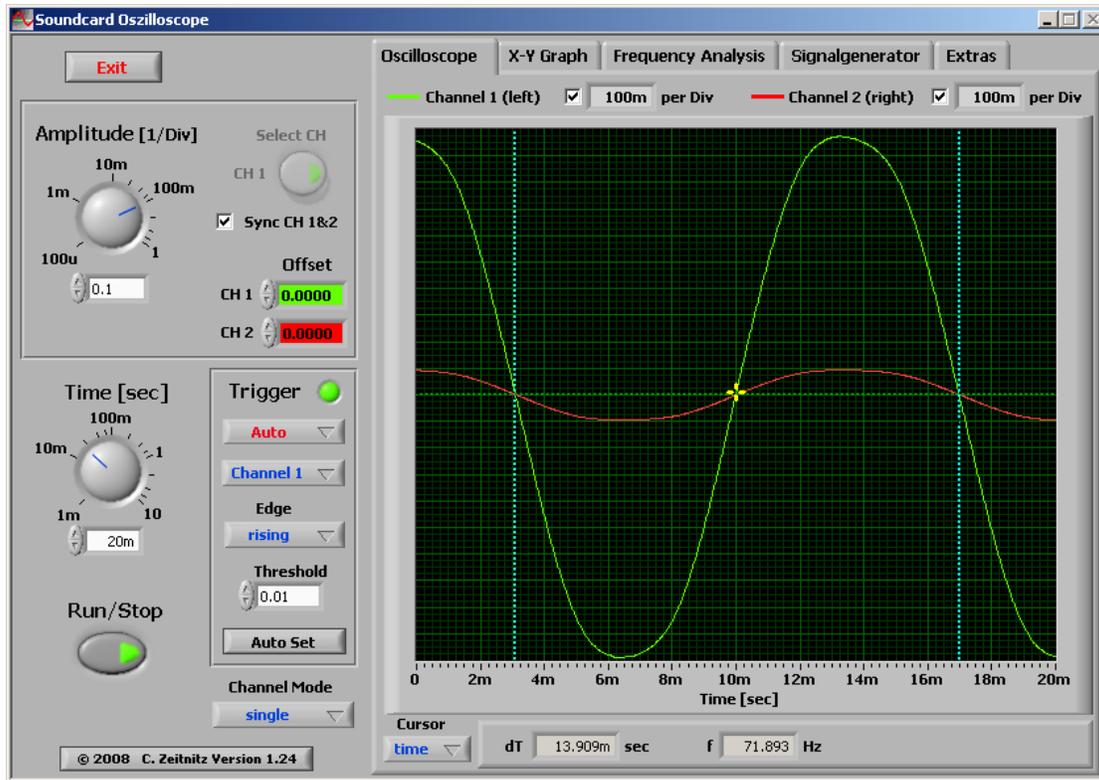
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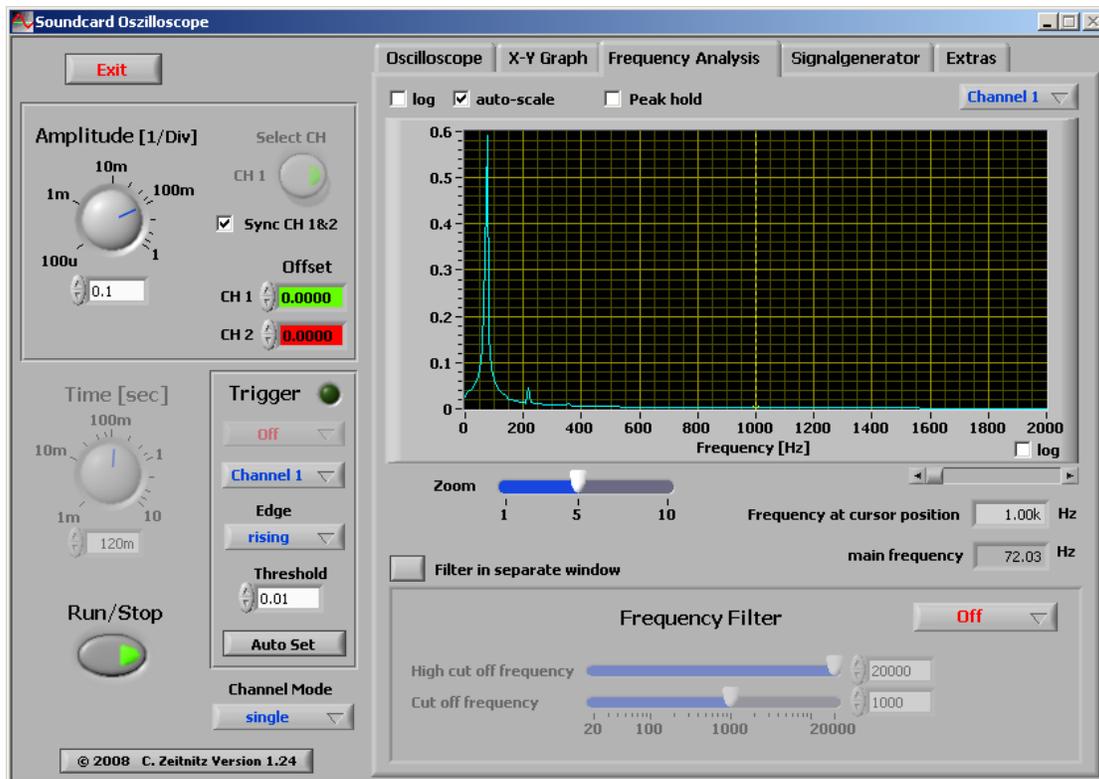Figure 6: Using time cursors to display frequency.

Figure 7: Using Frequency Analysis for main frequency and harmonics.

18. Select the "Frequency Analysis" tab located above the oscilloscope window. Choose a zoom of 5 and move the origin slider (just below and to the right of the Frequency axis) to reset the origin to zero. See Figure 7. The cursor was moved to measure a slight energy peak at the third harmonic.

Calibrating the 10x Attenuator:

1. Be sure you have successfully performed the initial calibration, described above.

2. Return to the Zeitnitz Oscilloscope tab.

3. Check that both attenuators inputs are connected together. The ANDY GEN output should still be approximately 0.740 volts RMS sine wave. Connect the GEN output to both attenuator inputs.

4. Set both attenuators to the 10x position. The waveform amplitude should be small in the Oscilloscope window.

5. Change the Zeitnitz Amplitude control to 0.01. You may move the knob, highlight and type, or use the arrows. Both waveforms should now fill the Oscilloscope window.

6. Use the voltage cursors to measure the peak-to-peak voltage. In this example, we measure 0.1975, multiplied by 10, because we are using the 10x attenuator circuit. This is about 1.975 volts, which is within experimental error of the expected 2.00 volts. See Figure 8.
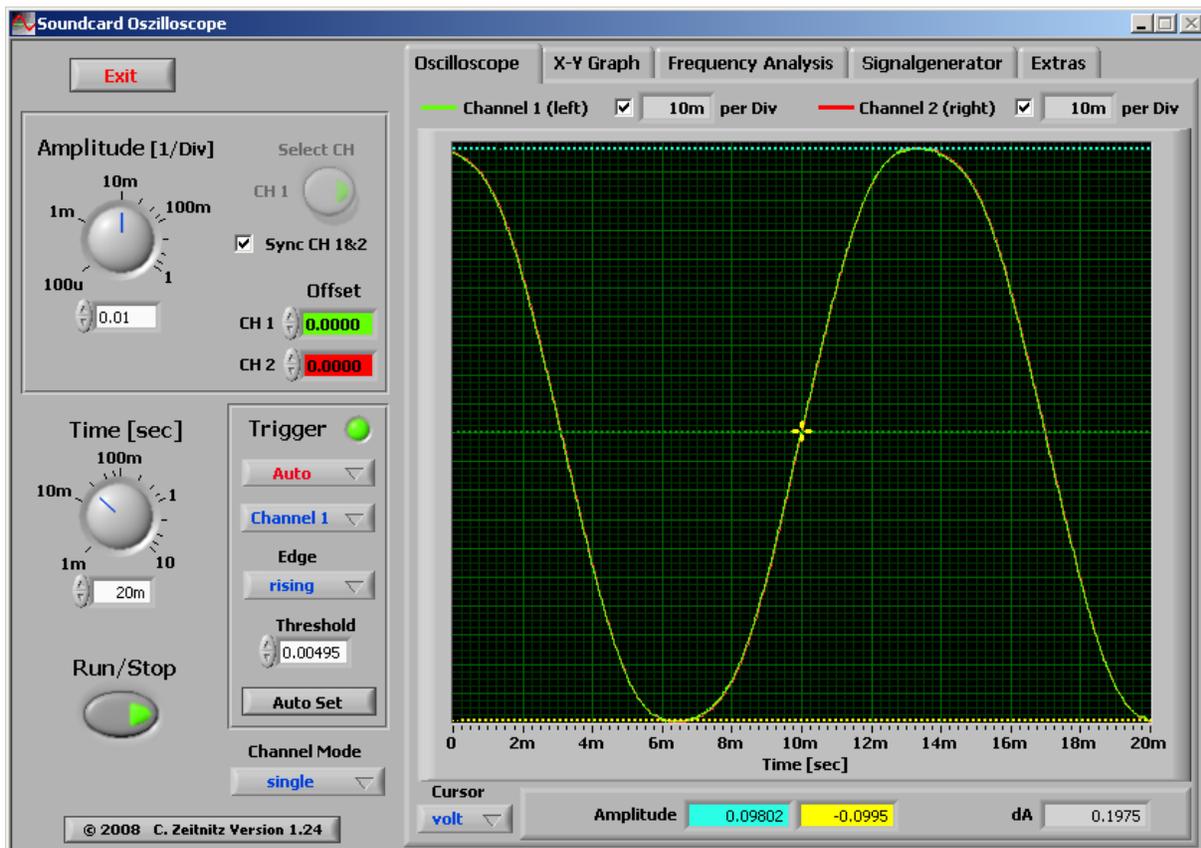

Figure 8: Using voltage cursors to measure 1.975 volts peak-to-peak in the 10x mode.

7. Change the Zeitnitz "Amplitude" to 0.2 volts per division. The waveforms will become smaller.

8. Highlight the green (Channel 1) offset control and type 0.3 <enter>. Highlight the red (Channel) offset control and type minus 0.3<enter>. Drag the trigger cursor (+) to the upper, green waveforms in the Oscilloscope window.

9. Slowly increase the ANDY GEN output, using the ANDY Amplitude trimpot, while watching the waveforms in the Oscilloscope window.

10. Use the voltage cursors to measure the maximum output of the ANDY GEN sine wave output into a 1.0 M ohm load. See Figure 9. Since we are using the 10x attenuator, multiply the measured voltage, dA, by 10 to obtain 9.60 volts peak-to-peak.
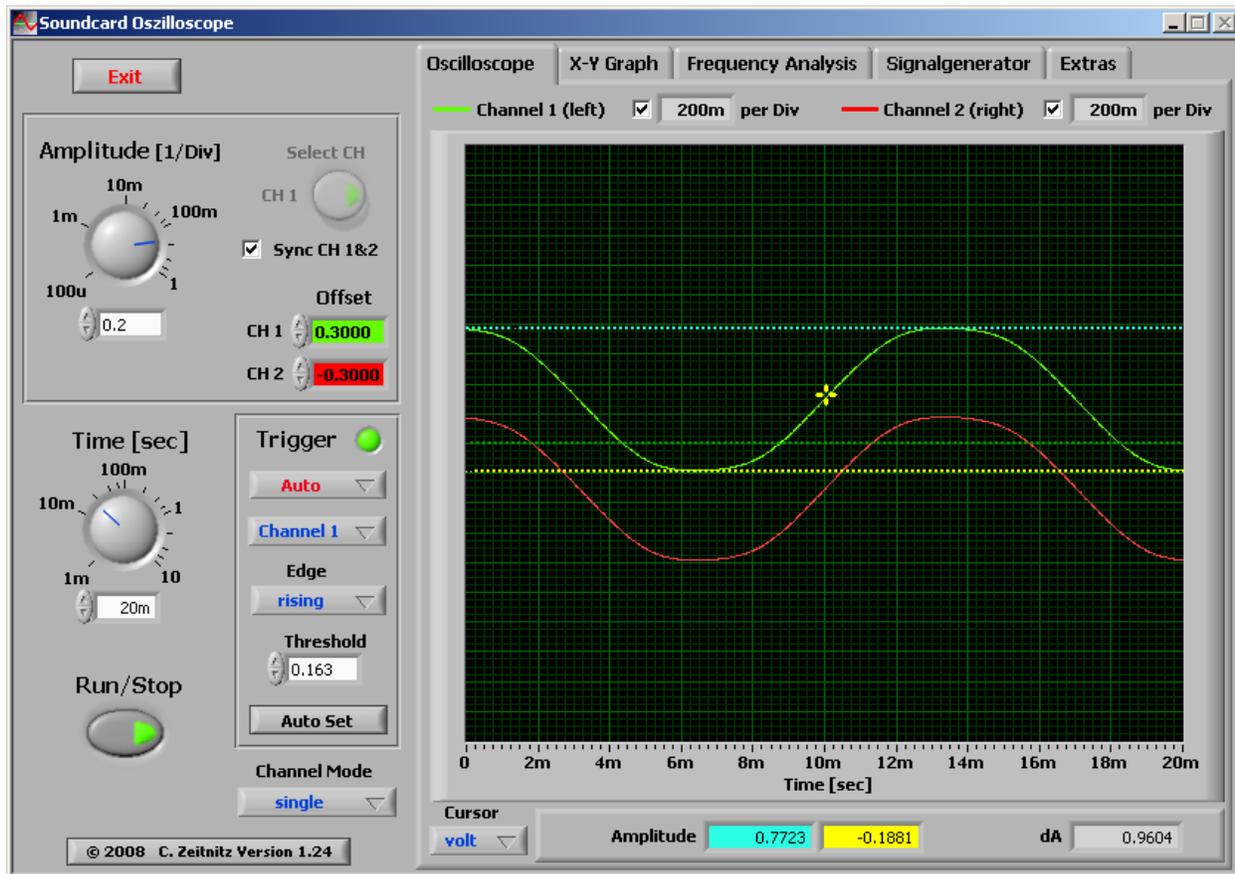

Figure 9: Maximum sine wave GEN output into 10x attenuator.

11. Using the MY-64 multimeter, on the 20V ~ AC scale, measure the GEN output voltage. In this example, we measured 3.60 volts RMS (10.08 V P-P). The Zeitnitz displays 0.9604. Since we are using the 10x attenuator, multiply by 10, to obtain 9.60 volts peak-to-peak, which is very close to the "attenuator+UCA202+Zeitnitz" value.

12. Since the UCA202 is AC coupled, the ANDY function generator offset cannot be measured. At low frequencies, the UCA202 input time constant significantly distorts a square wave. At 1.0 KHz, the "attenuator+UCA202+Zeitnitz" displays a

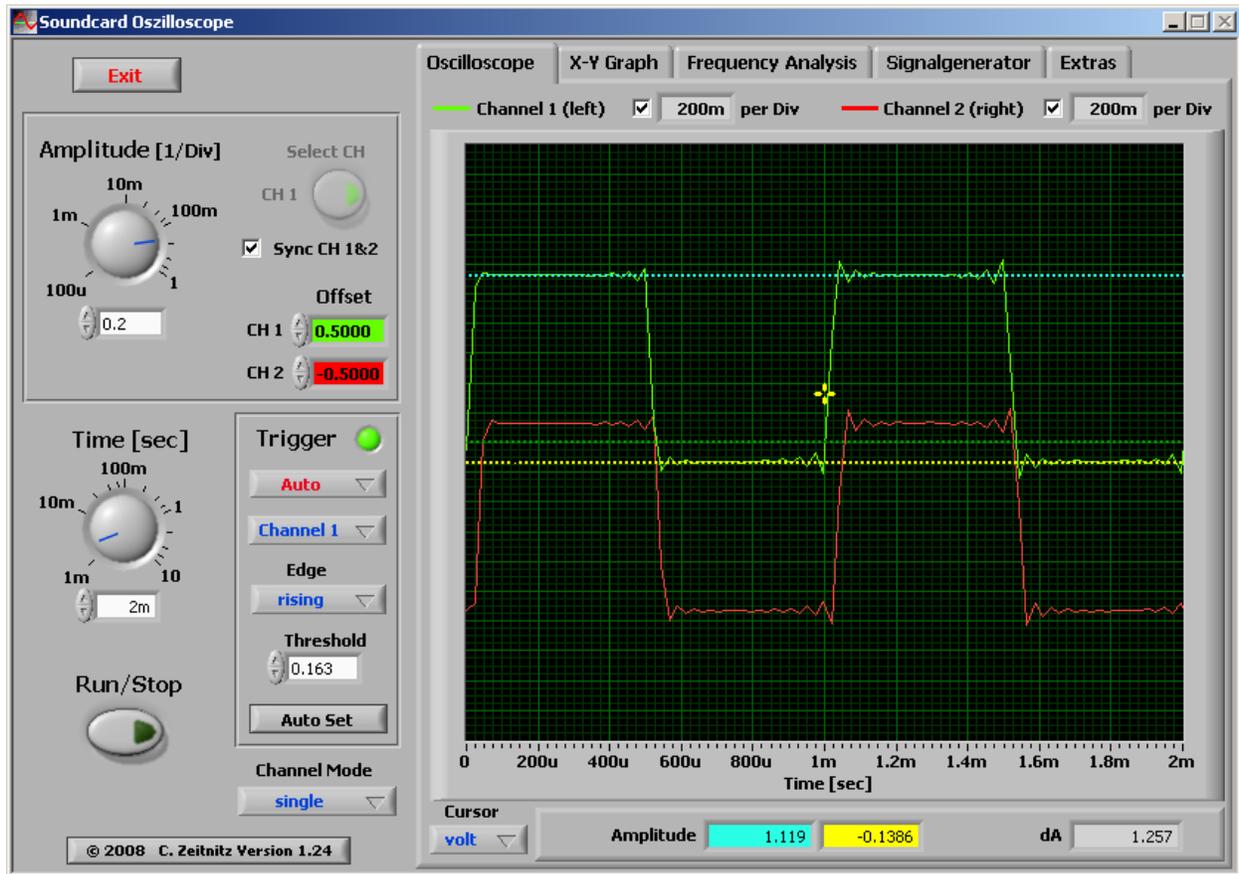reasonable square wave. See Figure 10.

Figure 10: 1.0KHz square wave at maximum GEN output into the 10x attenuator

13. To produce this figure, several tricks were used:

- The Amplitude was set to 0.2 volts per division by highlighting the Amplitude field and typing "0.2."
- The Run/Stop button was stopped to more accurately place the voltage cursors.
- The Offsets were adjusted to fill the display window.

Last Revision
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