Audacity – adopt an audacious approach to the study of sound

Audacity is open source software for recording and editing sounds and is available for Mac OS X, Microsoft Windows, GNU/Linux, and other operating systems. It may be downloaded from the SourceForge.net website, the world's largest Open Source software development web site. Open source promotes collaboration between developers and end-users to produce enduring, high quality software.

Introduction

For the last couple of years my younger son has been using various incarnations of this wonderful application to realise his musical creations by the use of multi-track recording and editing. It is extremely easy to use and files can be saved out as Audacity files (for future editing/mixing), *WAV* (the type of files you get on music Cds), *Ogg Vorbis* (a type of compressed audio file) and *MP3* (a compressed audio file format that most folk under the age of 25 will be very familiar with!). One of our SSERC staff recently attended a one-day course run by Tom Dickson (Tom.Dickson@smtp5.fife.gov.uk). Audacity was used to provide edited commentaries for video and PowerPoint files. The program must definitely have arrived since we hear that there was a talk about *'Audacity and Music'* at the *2006 Physics Summer School* in Glasgow.

After looking at the Science component of *Environmental Studies (5-14)* and the various *S3-S6 Physics syllabuses* (see *Curricular References*), it is apparent that Audacity can serve as an excellent tool for investigative work in the study of sound ... and the best bit ... it's free!

Equipment requirements

The first and most obvious requirement is that your computer should have a sound facilities fitted. On many inexpensive machines and laptops these are often integrated with the motherboard i.e. the main circuit board at the heart of the computer. Those who are interested in gaming and the like may have a separate soundcard fitted to cope with all the bangs and explosions. As for the speed of processor which you require, we've managed to get Audacity to run on computers running at 333 MHz, and right up to 3.1 GHz. You'll also need a microphone (mic). We used a perfectly satisfactory one, Cat. No. CS13516, priced at only £1.82 incl. vat, from CPC (Fig. 1). The final add-on for your sound experiments is a pair of speakers or, for a little extra cash, a pair with a sub-woofer (Cat. No. CS1283205) to give you these extra-low frequencies (Fig. 2).

Figure 1 - Simple desk microphone & stand

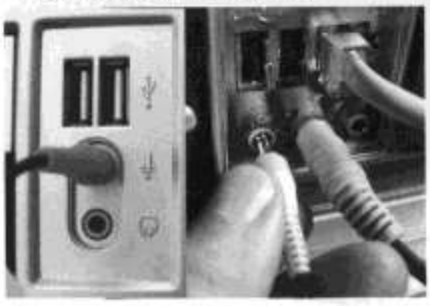
Figure 2 - Speakers & subwoofer system

Getting the software

Simply go to the download address (http://audacity.sourceforge.net) and then to the University of Kent mirror site link. You can save this executable file to your hard disc for installation on the computer you're on or to a pen-drive for set-up later on another desktop computer or laptop. This file is only 2.21 Mb so you'll not wait for hours downloading or installing it.

Setting up the computer

Before starting to record any sounds the computer settings need to be configured to receive them via the microphone. Plug the jackplug end of the mic into the pink colour-coded socket. This is often found to the rear of the computer (Fig. 3b) but newer machines can have a panel conveniently situated on the front (Fig. 3a). The sound output (green socket) should be connected to the speakers via the green jackplug as shown.



Figures 3a & 3b - Mic inputs (front & rear)

Go to *Start – Settings – Control Panel* then double click on *Sounds and Multimedia.* Choose the *Audio* tag at the top and then the *Volume* button within *Sound Recording.* A window (Fig.4) will appear on screen entitled *Recording Control.* Make sure the *Microphone slider control* is there and the *Select box* is ticked.

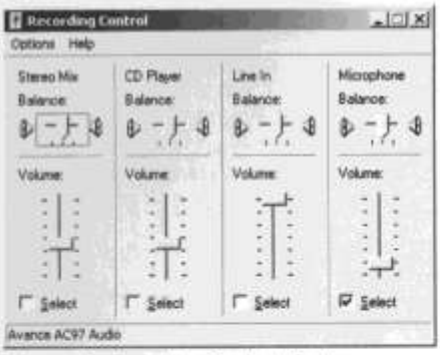


Figure 4 - Recording Control window

If there is no microphone area click on *Options – Properties,* select *Recording* and make sure the *Microphone* tick-box in the scrolling area at the bottom of the window is ticked. The *Microphone slider* should then appear in the *Recording Control window.* Click on the *Advanced button* and tick the *1 Mic Boost tick-box.* This boosts the signal from the microphone and effectively makes it more sensitive to any sounds (Fig. 5).

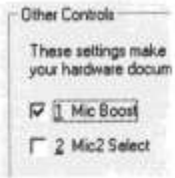


Figure 5

You may also need to adjust the *Volume Control.* This is accessible directly via a right-click on the wee speaker icon on the toolbar at the bottom of the desktop. Click on *Open Volume Controls* and the window appears on screen (Fig.6). This window is also accessible via the *Sounds and Multimedia* section of the *Contrio Panel.*

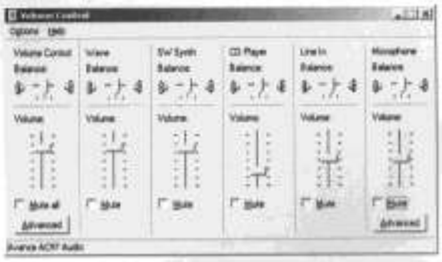


Figure 6 - Volume Control window

Make sure that the *Microphone tick box* is not *Muted.* If all is OK with the Recording and Volume Controls then you should be able to hear your voice being amplified when you speak into the microphone.

You are now ready to start up Audacity and use it as a tool to make and study sounds. This article will take you through the basics of :-

- recording & analysing sound waves
- using Audacity to generate sounds
- threshold of hearing
- vibrating air columns
- speed of sound experiment
- capture of sound pollution
- interference

Recording & analysing

When Audacity is installed on a computer it will put the application icon on the Desktop. Double click on this and the Audacity application starts (Fig. 7).

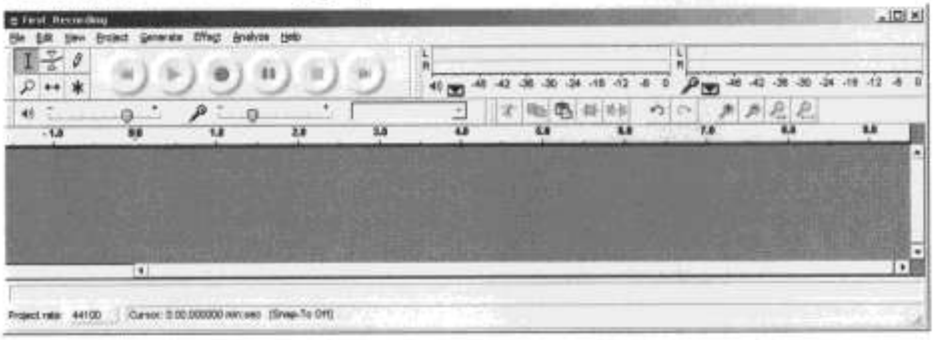


Figure 7 - Recording Control window

The six circular buttons control, from left to right, *Start of Recorded file, Play, Record, Pause, Stop* and *End of Recorded file.* Below these are two slider controls for *Playback Level* (speaker symbol) and *Recording Level* (mic symbol). Make sure the microphone is connected, set the *Recording Level* to about halfway and try a recording by pressing the *Red button* in the centre. A scrolling trace will appear in the grey area below – try making a few sounds – the recording will continue until the *Stop* or *Pause* buttons are pressed.

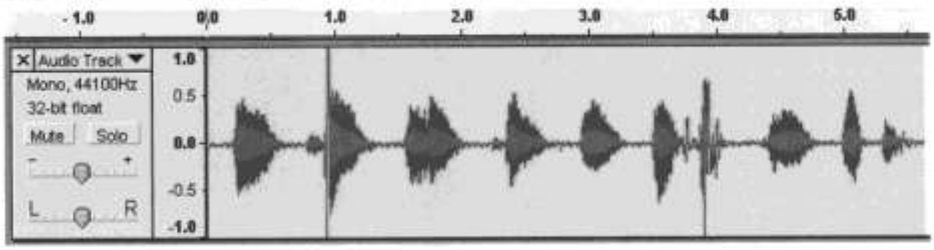


Figure 8 - Sample sounds recorded

Fig. 8 shows speech patterns of the letters of the alphabet from A to H. The *Recording Level slider control* can be adjusted so that the trace uses the full height +1 to –1. If the trace overshoots this scale then the recorded sound will be over-recorded and playback will be distorted. If the height of the trace is very small then the recorded sound will be under-recorded and weak.

Figure 9 - Selection Toolbar

The sounds can be analysed in closer detail by clicking on the *Selection Tool* (Fig. 9, 'I' symbol), selecting and highlighting an interesting area on the trace, then clicking on the *Zoom In* icon (wee magnifying glass with a + inside) on the *Edit Toolbar* (Fig.10). The display zooms in to show high detail.

Figure 10 - Edit Toolbar

Generating sounds

As well as recording sounds Audacity can be used as a sound generator. Click on *Generate – Tone...* then a *Sine, Square* or *Sawtooth* waveform can be selected and the *Frequency* (in Hz), *Amplitude* (0-1) and *duration* (in seconds) specified. Fig. 11 shows a tone which is Sine, 400 Hz and Amplitude 1 (full scale) for 5 s. These particular settings produce a virtually solid blue trace (Fig. 12) because the frequency chosen and the screen resolution cannot show individual waves. Click on the *Zoom In* icon 6 times and the sinusoidal trace can be seen (Fig. 13).

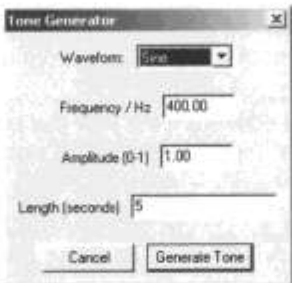


Figure 11 - Tone Generator window

Figure 12 - Tone Generator output - waves too close to resolve

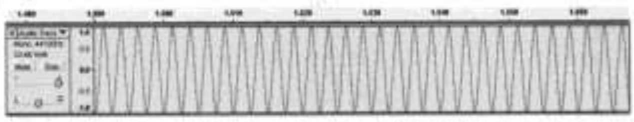


Figure 13 - Zoomed-in view shows individual sound waves

Threshold of hearing

We can put the sound-generating ability of Audacity to good use by generating a number of tone bursts of steadily increasing frequency to examine the threshold of hearing. Interspersing these tone bursts we have slots of generated silence (Fig. 14). The task can be made more akin to hearing tests by not increasing the frequency by steady increments, randomising the sound bursts, blindfolding the subjects and using high quality headphones. It should also be noted that these tests are as much a test of the loudspeaker/headphone equipment you use as it is of what frequencies can be heard. If you use a sub-woofer then the low frequency bursts are pretty impressive.

Figure 14 - Tones of increasing frequency

You can also test the ability of your microphone to pick up pure tone sounds by playing the tone-bursts and recording simultaneously on another track. For this to happen select *Edit – Preferences...* then put a tick in the Play other tracks while recording new one tick-box.

On Fig. 15 it can be seen that the combination of the loudspeaker used to make the sound and the frequency-response of the microphone results in an uneven reproduction of sounds across the frequency spectrum. This is quite normal and one of the reasons why graphic equalisers are a good idea.

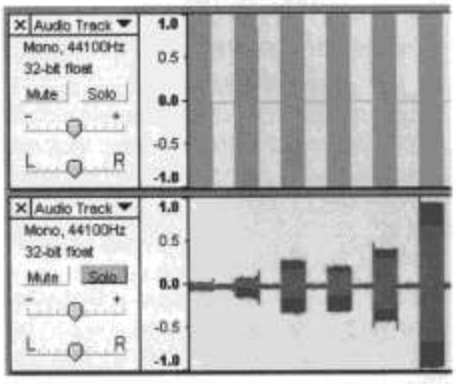


Figure 15 - Microphone frequency response

Vibrating air columns

Here we look at the sounds produced by blowing air (Fig. 1) over the neck of two sizes of glass medical-flats bottles (19 cm and 15.5 cm tall). The top trace is the larger bottle. The *Audacity* software can be used to analyse the frequencies produced by the two bottles. Ten wavelengths (10λ) on the top trace are highlighted and the times for the start, end and duration of the selection are displayed (Fig. 16).

Figure 16 - Time for 10λ   Selection: 0:00.493861 - 0:00.535171 (0:00.041310 min:sec)

Big bottle - 10 wavelengths correspond to a time period = 0.04131 s (Fig. 18, top)

Therefore 1 wavelength has a period (T) = 0.004131 s

Frequency (f) = 1 / T = 1 / 0.004131 = 242 Hz

Small bottle - 10 wavelengths correspond to a time period = 0.032591 s

Therefore 1 wavelength has a period (T) = 0.0032591 s

Frequency (f) = 1 / T = 1 / 0.004131 = 307 Hz

The calculated frequencies can be checked (Fig. 19) by generating a short burst of each frequency and see if it sounds the same as the recorded one. This experiment is just one of many which can be done in this vein. Look also at pukka instruments and resonant frequencies in tubes which can be varied in length with the use of a plunger.

Figure 17 - Blow gently over the bottle

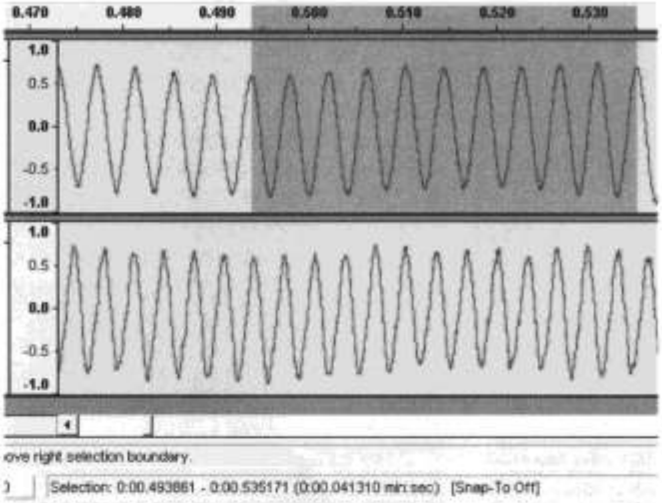


Figure 18 - Big bottle (top, 242 Hz), small bottle (bottom, 307 Hz)

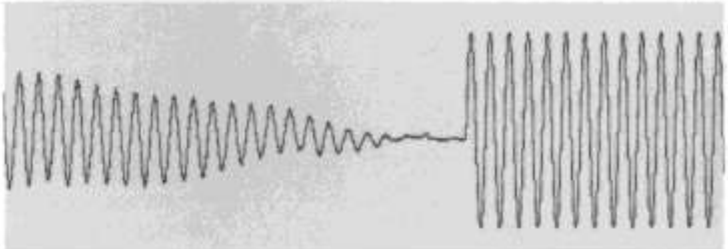


Figure 19 - Recorded waveform & generated tone of predicted frequency

Speed of sound experiment

Ok, so this has all been done before with hammers, contacts, oscilloscopes or digital stopclocks and the like. We were interested, however, to see if this could be done within the confines of the desktop (the real one that is!) and the wall opposite (39 cm away from the computer screen).

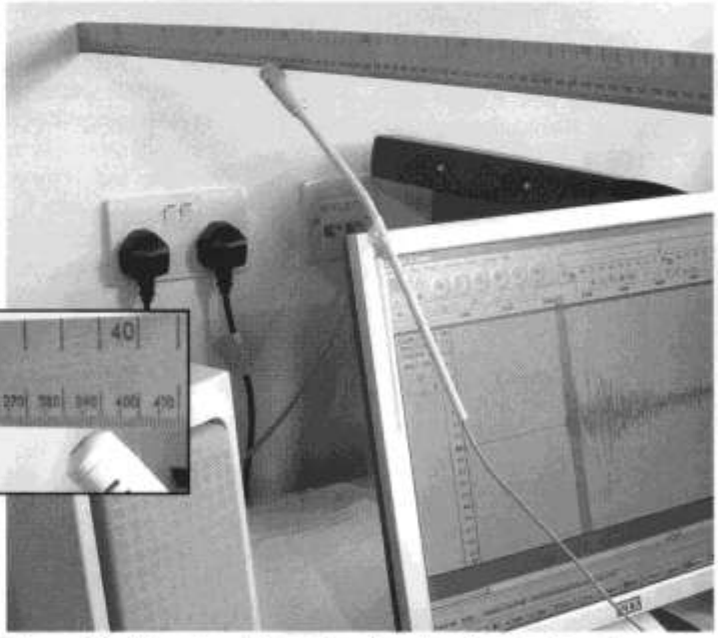


Figure 20 - Measuring distance from the microphone to the wall

Another beauty of this set-up is that you don't have any triggering to worry about and you can be quite relaxed about when the sound measurement is taken and that you'll not miss anything with readings being taken about every 0.00002 s. At that rate Audacity says that the hard disc can take over 100 hours of recording!

The microphone was blu-takked to the monitor, 0.39 m from the wall (inset Fig. 20). Recording was started with the red button and a sharp clap carried out about the same distance in front of the screen. This distance is not important. However, the loudness of the clap and recording level should be set in order to achieve full scale.

The short duration of the clap being recorded as well as the echo from the wall can be highlighted and zoomed-in on until a trace, similar to Fig. 21, is obtained. The time between initial sound and the echo was measured (grey area) as 0.002313 s (t). Therefore the sound had taken this time to travel 0.78 m (d).

The **speed of sound (v)** is therefore calculated to be $\boldsymbol{d / t = 0.78/0.002313 = 337\ ms^{-1}}$

Try varying the distance between the microphone and wall. A large sheet of dense material could replace the wall as reflector of the sound if one is not nearby.

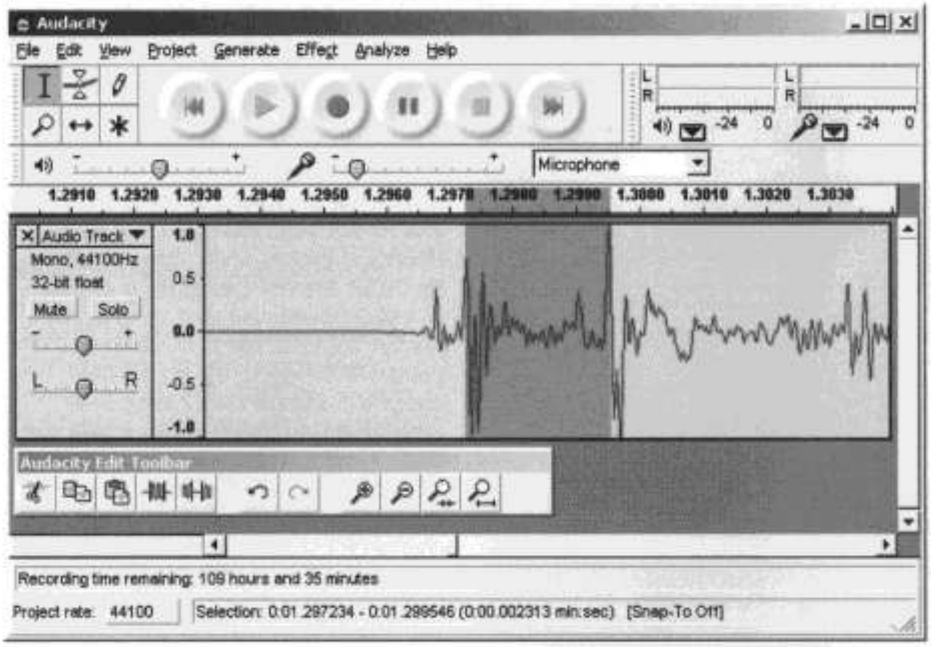


Figure 21 - Speed of sound experiment. Time between clap and echo is highlighted.

Noise pollution

There are many activities worth exploring with regard to noise pollution. In our ever-increasingly noisy environment we need to find ways of measuring sound levels which do not rely on our subjective perceptions. This is because the irritation factor of some noises e.g. babies crying, dogs barking, cats wailing etc., are more difficult to measure than the 'powered' noises emanating from the engines of cars and aircraft or sound systems blaring out from houses and cars.

We went with a microphone and laptop running Audacity to a busy road (Fig. 22).

Figure 22 - Noise pollution trace from a busy road.

The areas of dense blue correspond to particularly busy traffic flow – the greater amplitude corresponds to greater noise. The tall peaks which are wide equate to something like an articulated lorry passing by. How could we use information like this to better design screening for busy roads? Try and design experiments to test the efficiency of sound-absorbing material e.g why do workers require ear-defenders?

Interference

Here we go back to generating tone-bursts of increasing frequencies with Audacity's in-built tone generator. The same tone comes out of the two speakers as we simultaneously record with the microphone panning across between them. You can see that the pattern of high and low volume, corresponding to constructive and destructive interference, changes as the frequency increases from left to right.

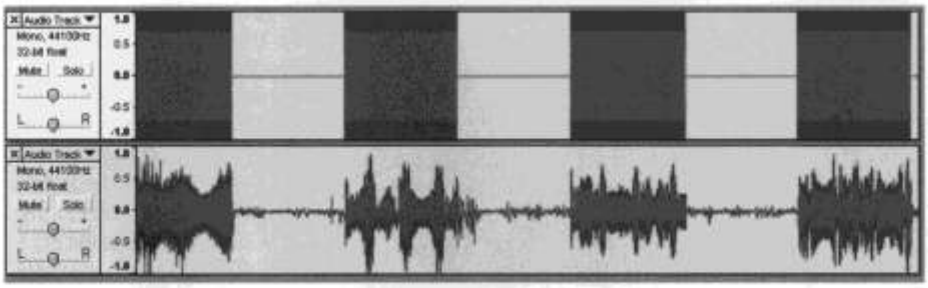


Figure 23 - Interference patterns produced as microphone pans between two speakers

Concluding remarks

We hope that this wee article has given you the spur to go on and explore the world of sound with Audacity. Other applications we've tried are transmission of sound in wood, Doppler Effect, spectrum analysis of animal sounds and damped oscillation. We hope to feature these in future issues of the Bulletin

Let us know how you get on, make it fun and give us your ideas for further experiments.

Curricular References

ISE 5-14 learning outcomes

EF-C1.3 - link sound to sources of vibration, Science Framework for Planning – Group 10 (Light & Sound)

(http://www.ise5-14.org.uk/Prim3/New_Guidelines/Levels/topics-c.htm#2-1-3)

EF-D1.4 - use the terms 'pitch' and 'volume' to describe sound

(http://www.ise5-14.org.uk/Prim3/New_Guidelines/Levels/topics-d.htm#2-1-4)

EF-D1.5 - explain what happens when sound passes through different materials

(http://www.ise5-14.org.uk/Prim3/New_Guidelines/Levels/topics-e.htm#2-1-5)

EF-F1.3 - describe the relationship between pitch and frequency and between loudness and amplitude

(http://www.ise5-14.org.uk/Prim3/New_Guidelines/Levels/TOPICS-F.HTM#2-1-3)

Standard Grade Physics

Unit 3, Section 2, Health Physics, Using Sound - The stethoscope, Investigate range of hearing experiment with signal generator and loudspeaker, Noise pollution.

Unit 3, Section 6, Health Physics, Practical Investigation – noise level measurement / pollution/ absorption.

Physics (Access 3 & Intermediate 1)

Unit (Sound and Music), Section 4.1 – Sound waves, Section 4.2 – Speed of sound, *Section 4.3 – Using sound, Section 4.4* – Amplified sound

Physics (Intermediate 2, Higher and Advanced Higher)

Unit (Waves and Optics), Section 3.1 – Waves

Addresses

SourceForge.net - http://sourceforge.net/docs/about

Download address for Audacity app. - http://audacity.sourceforge.net

Great site for browsing and listening to music and sound effects files – snippets can be recorded by Audacity :-

http://www.audiolicence.net/

Mic & speakers - http://www.cpc.co.uk