SOUND SENSORS

Sound Sensors Sensors is part of the **SEP 'Sensors' pack**

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All screendumps for MultiMedia Sound version with the agreement of Cambridge Science Media

SEP
Science Enhancement Programme

The Science Enhancement Programme (SEP) is part of Gatsby Technical Education Projects. It undertakes a range of activities concerned with the development of curriculum resources and with teacher education. For further information, visit www.sep.org.uk

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SOUND SENSORS

INTRODUCTION

Virtually all students will have seen and heard of a microphone, so it is a good sensor to start work off with. The key point to get across, regardless of whether the type of microphone is a moving coil or dynamic, ribbon, crystal or ceramic, capacitor or carbon, is that the effect of sound on it is to produce a varying voltage.

The **dynamic microphone** consists of a coil attached to a small cone which moves in response to sound. This coil (and cone) is positioned in a magnetic field so that as they move an electromotive force (e.m.f.) or voltage is generated across the coil. The voltage is then amplified as required. It is much like a loudspeaker in reverse.

The **ribbon microphone** has a narrow aluminium ribbon, corrugated to increase its flexibility, suspended between the poles of a magnet. In response to sound this ribbon moves in the magnetic field and again generates a voltage, this time between the ends of the ribbon. This voltage is amplified as required.

The **piezoelectric, crystal or ceramic microphone** depends for its working on the **piezoelectric effect** discovered by Pierre and Jacques Curie in 1880. Its key component is usually a synthetic ceramic crystal of barium titanate or lead zirconium titanate. When a sound compression reaches it, the crystal is slightly compressed. This produces a positive charge on one side of it and a negative charge on the other, and so results in an electric field and a voltage being generated across it. The crystal gas-lighter generates its spark in the same way by the user compressing the crystal, generating a high voltage across the spark-gap. If you have one of these gas-lighters then a brief demonstration of it would be useful, otherwise some short video clips are available to see on the American Chemical Society web-site Chemistry comes alive - see useful weblinks.

The **capacitor microphone** effectively consists of two plates, one fixed and one moveable, with the capacitance varying according to the spacing between the plates. A voltage of around 50V is usually applied across these plates. Sound causes the moveable plate to move and so change the capacitance of the system. With the voltage fixed between the plates this movement causes a change in the charge on the plates and so a current flows into and out of the system. This current flow through a load resistor generating a voltage which can then be amplified.

The **carbon microphone** was in widespread use in telephones in the past. It consisted of a container filled with carbon granules. To the back of the container, and in contact with the granules, was fitted a fixed metal plate and to the front a moveable thin metal diaphragm, also in contact with the granules. Electrical contacts were made with the metal plates and diaphragm and a small electrical current passed between them through the carbon granules.

Sound on the diaphragm caused the granules to compress and decompress, so varying the contact between them. This produced a change in resistance and so a change in current. A changing current across a resistor could then give rise to a varying voltage, as with the other microphones.

THE ACTIVITIES

Note 1: *Avoid explanation so of why compressing this type of crystal produces a voltage.*

Note 2: *If you have not got a piezoelectric microphone then use a microphone insert.*

The easiest type of microphone to demonstrate the working of is the piezoelectric, crystal or ceramic microphone which gives an output voltage high enough to register on a multimeter set to a millivolt range.

Whilst you could simply show that whistling into a microphone connected to an oscilloscope will display the waveform of the whistle, that would hardly provide an investigative activity: the sound activity provided is both investigative and is based on a **real-life technique** related to **quality control in the food industry.**

The first stage is to obtain and store waveform and frequency spectrum traces of crackers/wafers being snapped. The two versions of the activity describe how to use Pico Technology's *DrDAQ* with *Picoscope* or Cambridge Science Media's *Multimedia Sound*. The former has a built-in microphone and the latter uses a standard computer microphone for its input. Both have the equivalent of storage oscilloscope and spectrum analyser modes and so can display the waveform traces and the frequency spectra produced by snapping each sample.

It is essential that working conditions are reasonably quiet, as the sounds of the snapping are not loud,.

Students can then examine these traces to see if they can distinguish between the types of cracker/wafer using (i) the waveform traces alone, (ii) the spectrum analyser traces alone, or (iii) if it is best to use both the waveform and the spectrum analyser traces. To make a puzzle of the activity the traces are stored on the computer with simple codes such as s1w, s2w, s1s, s2s etc. to represent 'sample 1 waveform', 'sample 2 waveform', 'sample 1 spectrum analysis' and 'sample 2 spectrum analysis' etc. for Pico *DrDAQ*, and s1ws, s2ws, s3ws etc. for Multimedia Sound. Following this, other students then snap the same set of crackers/wafers and try to match each type with the stored traces.

Note*: whilst students might like to try to find out the reasons for the differences, bar simply that the samples have 'gone soft', that would involve very complex research well beyond what most could achieve pre-18.*

Students could also compare crackers/wafers fresh from the packet with those left in the air for a day or a week to see how the traces differ. The amplitude of traces tends to be smaller (softer snap) when samples are not fresh, and there are usually fewer high frequencies in the frequency spectrum trace. **In real-life** the waveforms and spectra of perfect products would be stored on computer and those of quality control test samples compared with them. If these differed greatly from the perfect traces then consideration would need to be given to the production process to get the products back to perfect.

Useful web links

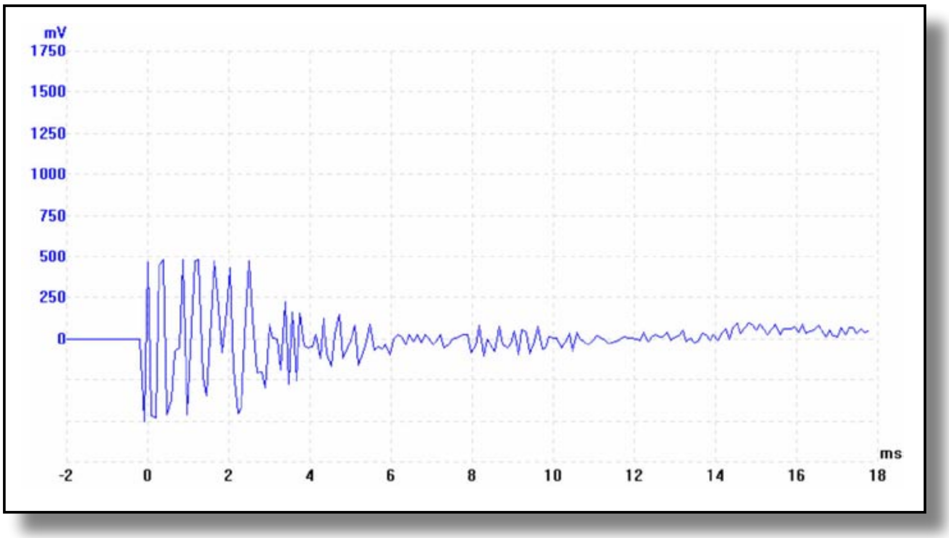
American Chemical Society Chemistry comes alive! – Piezoelectric Effect
http://jchemed.chem.wisc.edu/JCESoft/CCA/CCA2/MAIN/PIEZO/CD2R1.HTM
Here are some video clips showing how compressing certain crystals can produce a high voltage through the piezoelectric effect.

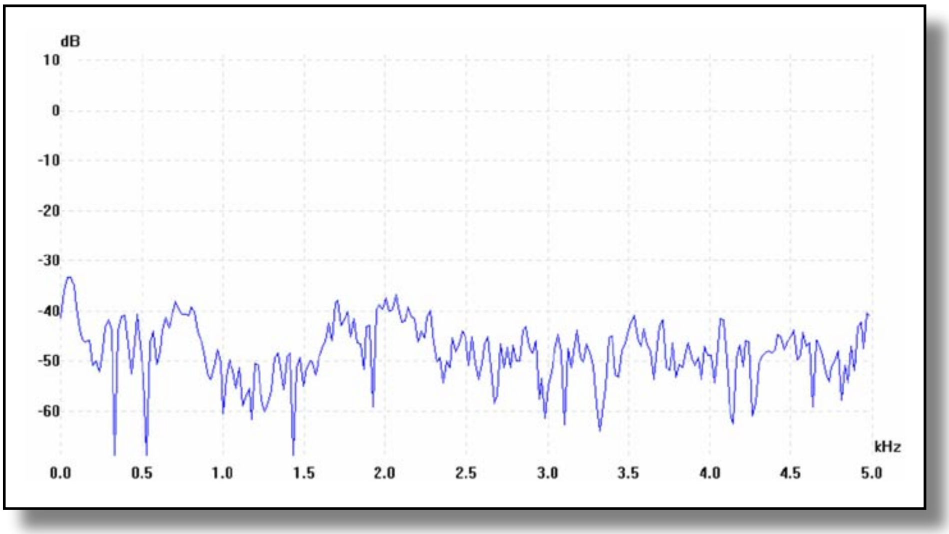
FFT Tutorial
http://grus.berkeley.edu/~jrg/ngst/fft/fft.html
A useful website if you wish to know more about FFT, but one for teachers only.

Quality Control in Food Processing Businesses
http://www.itdg.org/docs/technical_information_service/quality%20control.pdf
In a very short space this website gets across the main message of what quality control in the food industry is about.

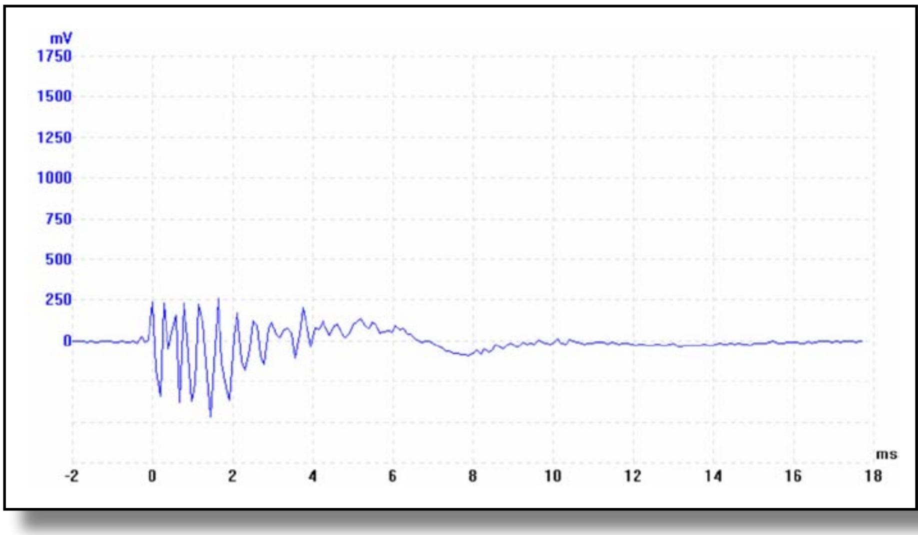
Stable Micro Systems
http://www.stablemicrosystems.com
Students can get a good insight into many of the testing techniques used in the food industry by looking at this manufacturer's website.

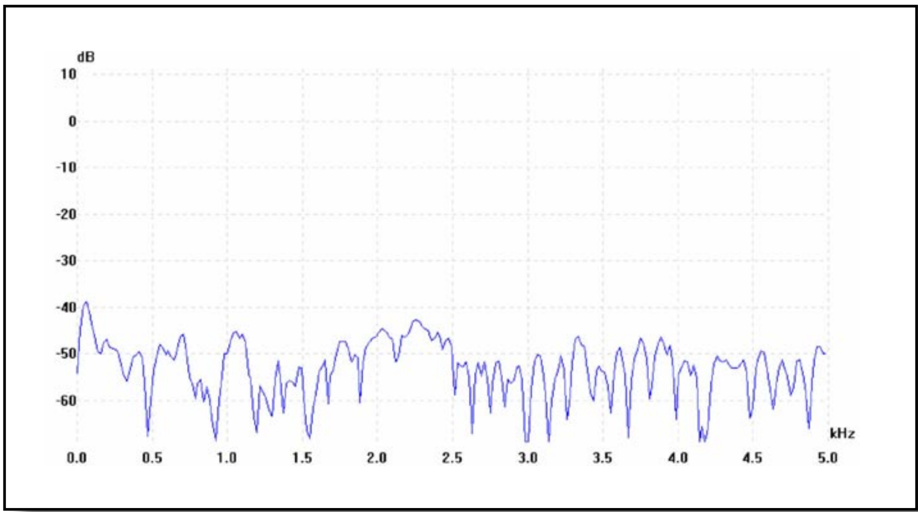
EXAMPLE WAVEFORM AND SPECTRUM ANALYSIS TRACES: PICOSCOPE ON DRDAQ



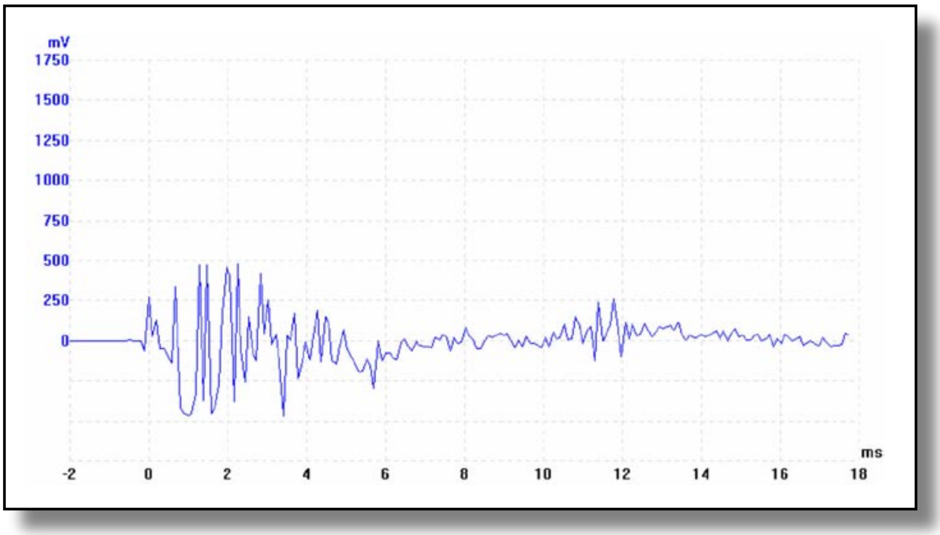


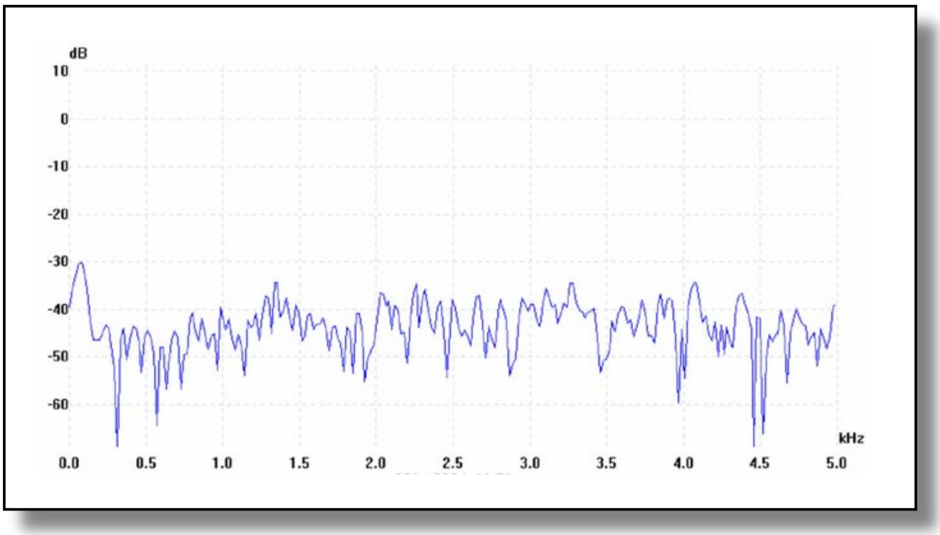
Askey ice-cream wafer



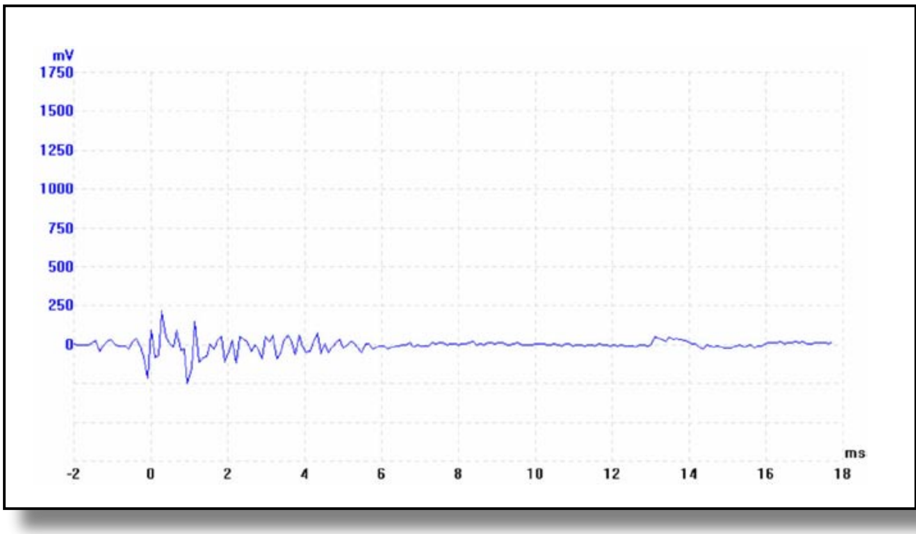


Cream Cracker





Crackerbread


mV
1750
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6
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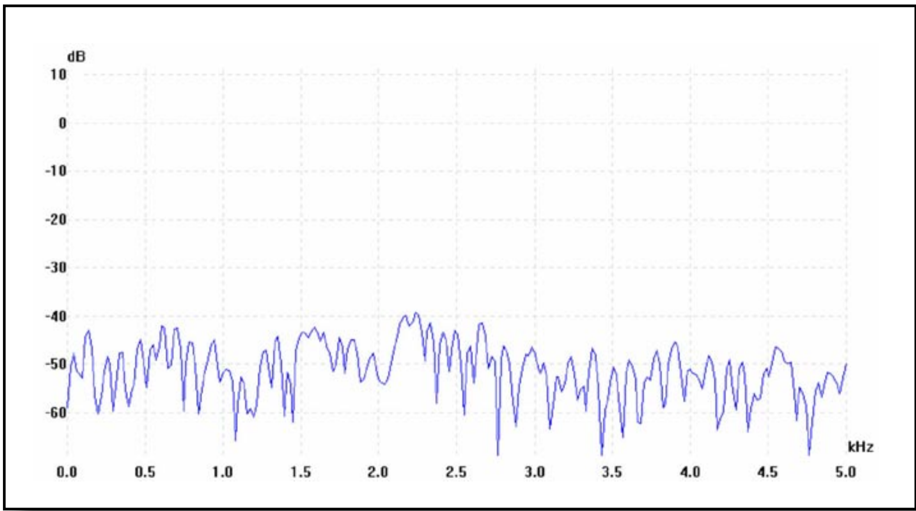
12
14
16
18


dB
10
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-10
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-30
-40
-50
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kHz
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1.5
2.0
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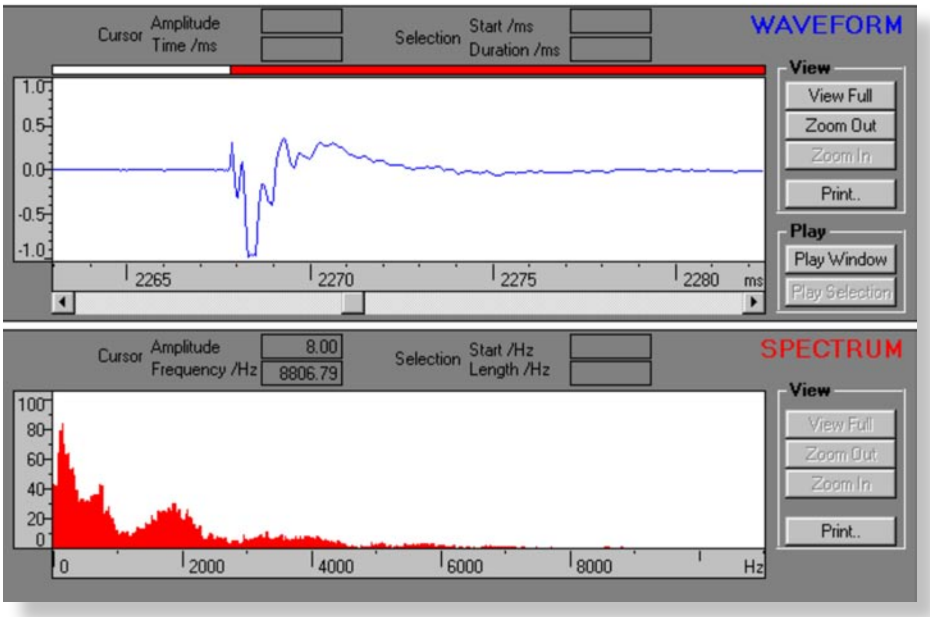
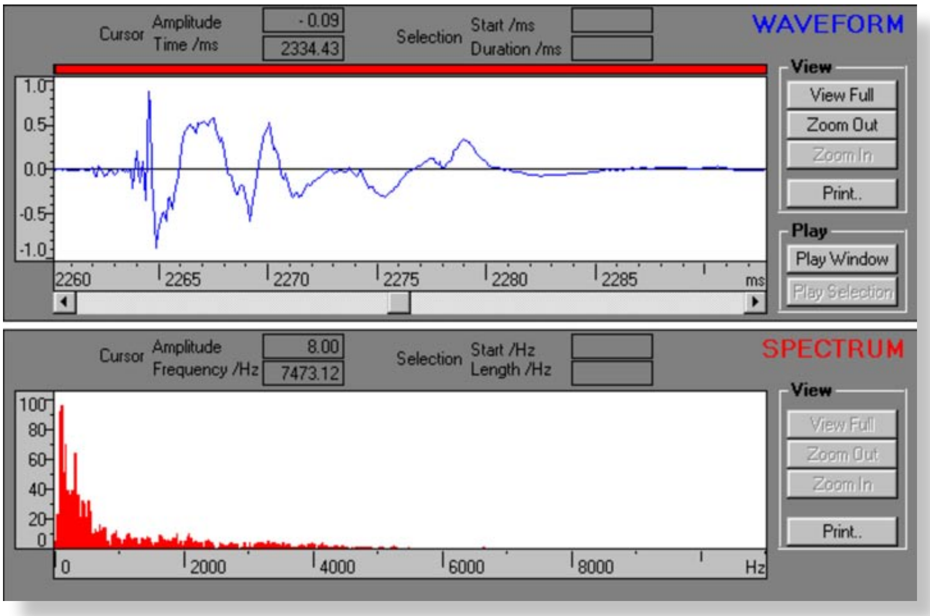
3.0
3.5
4.0
4.5
5.0

Ryvita

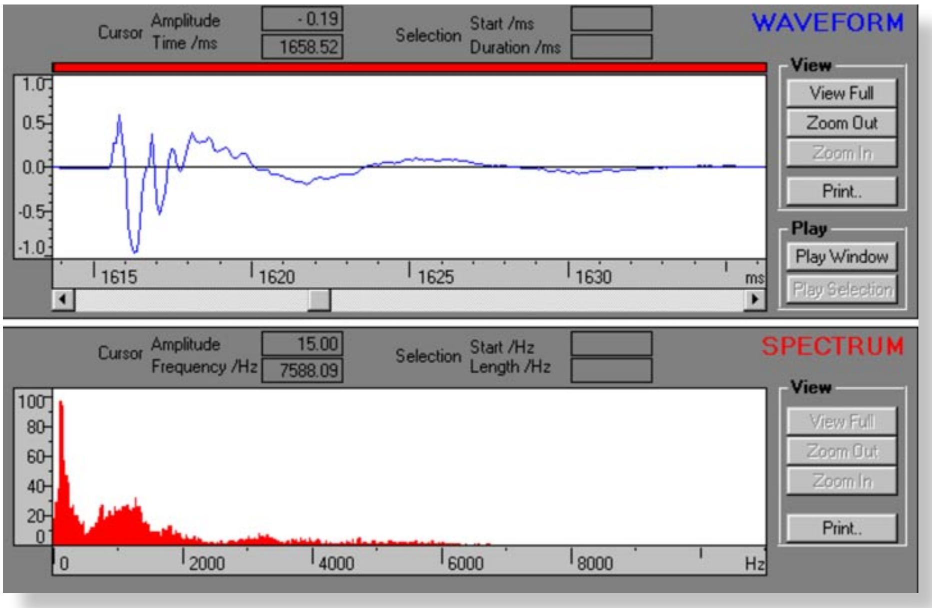
EXAMPLE WAVEFORM AND SPECTRUM ANALYSIS TRACES: MULTIMEDIA SOUND



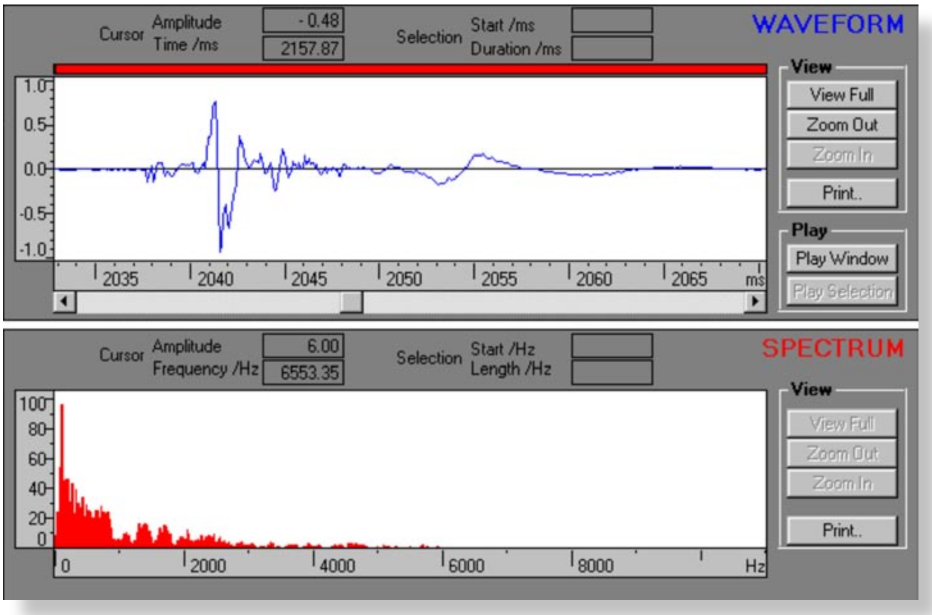
Askey ice-cream wafer



Cream cracker



Crackerbread



Ryvita

SOUND SENSORS: TECHNICAL NOTES

INITIAL DEMONSTRATION OF THE FACT THAT SOUNDS AT A MICROPHONE PRODUCE A CHANGING VOLTAGE

Equipment:
Crystal microphone or microphone insert
High impedance digital multimeter – millivolt range

Solder two leads and two 4mm plugs to the microphone insert. Plug the insert directly into the multimeter. Speaking fairly loudly into the microphone insert should produce a change in voltage on the multimeter's display.

USING A MICROPHONE TO INVESTIGATE CRISPNESS WITH CAMBRIDGE SCIENCE MEDIA'S MULTIMEDIA SOUND

Equipment:
Computer(s) and associated monitor(s), keyboard(s) etc.
Multimedia microphone (eg, Maplin Electronics HW70M)
Multimedia Sound CD-ROM (Cambridge Science Media)
Various makes of cracker and wafer

Plug a microphone into each computer in use.

On each computer a sub-folder of 'Csmsound' should be set up called 'Sounds' into which the students can save the various sound files produced. If the computer(s) are networked it is likely that the worksheet will need some modification before use.

USING A MICROPHONE TO INVESTIGATE CRISPNESS WITH PICO TECHNOLOGY'S DrDAQ AND PICOSCOPE

Equipment:
Computer(s) and associated monitor(s), keyboard(s) etc.
DrDAQ (Pico Technology Limited) and associated cable
Various makes of cracker and wafer

Plug *DrDAQ* into the appropriate port on each computer to be used.

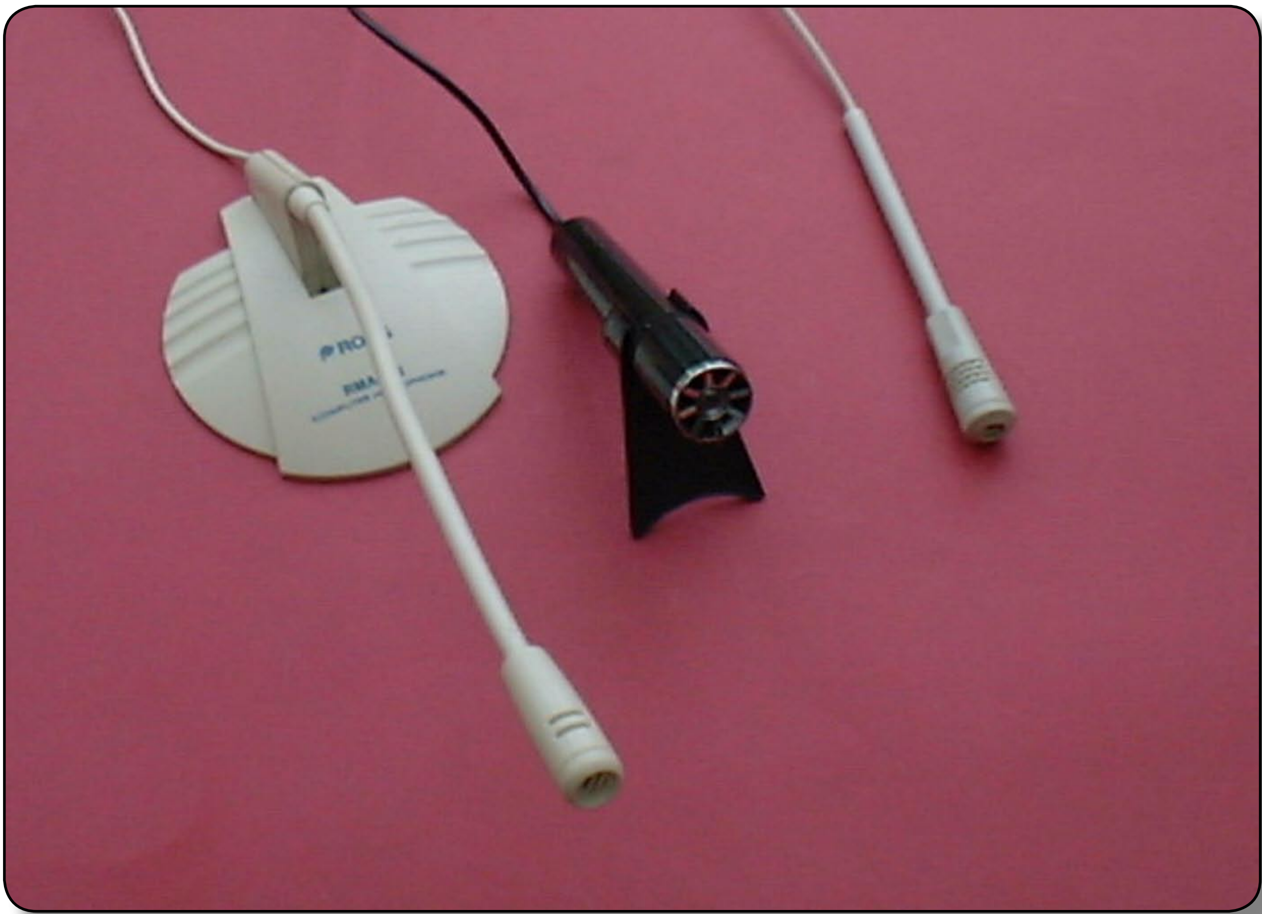
On each computer a sub-folder of 'Pico' should be set up called 'Sounds' into which the students can save the various sound files produced. If the computer(s) are networked it is likely that the worksheet will need some modification before use.

In a 'noisy' laboratory – electrical noise as well as sound – the suggested trigger level of 10 might well need increasing to 20 or more to avoid a trace being obtained before the crackers/wafers are snapped.

About Sound Sensors

Types of microphone

Microphones are the best known type of sound sensor and they come in a number of forms: the **moving coil or dynamic microphone**, the **ribbon microphone**, the **capacitor microphone**, the **carbon microphone**, and the **piezoelectric or crystal microphone.**



Range of microphones

How does a microphone work?

When the pressure of a sound wave reaches a microphone it generates a voltage. In most cases these voltages are very small and so need amplifying to make them useful.

About Sound Sensors

Uses

Perhaps the most common use of a microphone is to detect and, as a result of amplification, boost the sound of music or of a speaker.
However, there are many other uses of microphones, not all in the frequency range that we call sound. For example,

- **Hydrophones** use a piezoelectric microphone to detect the echoes of sounds transmitted by ships searching for shoals of fish, wrecks, or just to check the depth of water below them.
- In medicine, an **ultrasound scanner's** transmitter and receiver also use the piezoelectric effect to both create and detect ultrasound (very high frequency 'sound' not audible to us).

Wafer production (courtesy of Nestlé)

- In the mid-1990s sound was also used to check the freshness and quality of biscuits and wafers, and vegetables such as lettuce and broccoli, simply examining their crispness by snapping them. The sound sensor activities describe how you can try this out for yourself.

Activity (i) - Using a microphone to investigate crispness with DrDAQ

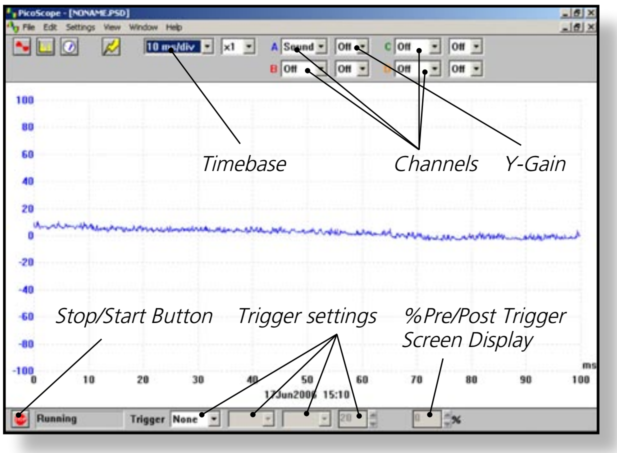
Procedure

Computer and DrDAQ set up to examine crispness

Note: If you are connected via a network you may need to obtain additional instructions.

- Before the computer is switched on, check that *DrDAQ* has been plugged into the computer.

Activity (i) - Using a microphone to investigate crispness with DrDAQ



DrDAQ opening screen

Switch on and load the *PicoScope* software. If necessary enlarge by clicking the x in the top right-hand corner of the screen to provide a full screen display as shown with the program already running.

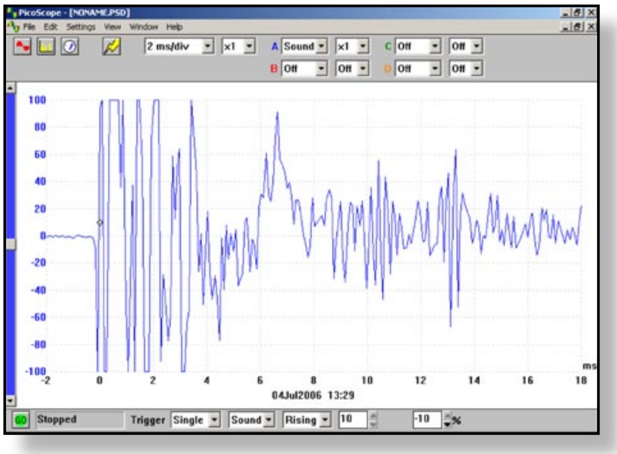
- Click the **STOP** button in the bottom left-hand corner of the screen
- Adjust the **Timebase** setting to 2 ms/div with an X-gain of x1. Set **Channel A** to **Sound** and its Y-gain to x1. Leave Channels B, C and D off.

Note: If the program appears to have frozen at any time then it can usually be unfrozen by pressing the F10 function key. If this does not succeed then close down the program by pressing the **Ctrl**, **Alt** and **Delete** keys simultaneously, and then restart the program.

- Now set the **Trigger** to **Single** (Click the **OK** button in response to the warning message that appears), **Sound, Rising, 10** and the **Pre/Post Trigger Screen Display** to **-10%.** The last of these lets you set when the trace is started from, in this case the first 10% of the display is prior to the sound being produced. It ensures that all the trace is captured if required.

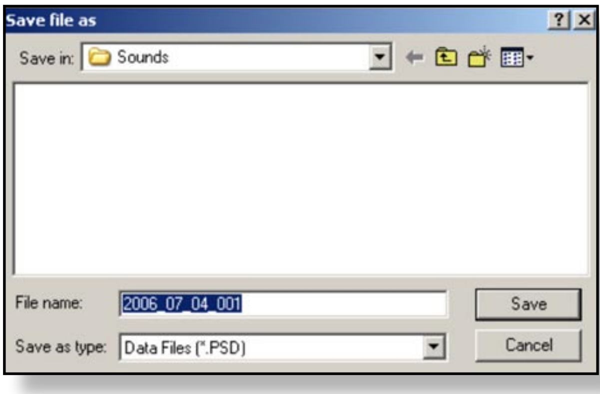
Note: If there is a lot of noise – electrical or sound – you may have to raise the trigger level to 20 or more to prevent triggering before you have snapped the cracker/wafer.

- Select a cracker/wafer, noting down what variety it is. Now click the **GO** button and snap the cracker/wafer next to the on-board microphone. You should obtain a display something like the one shown.



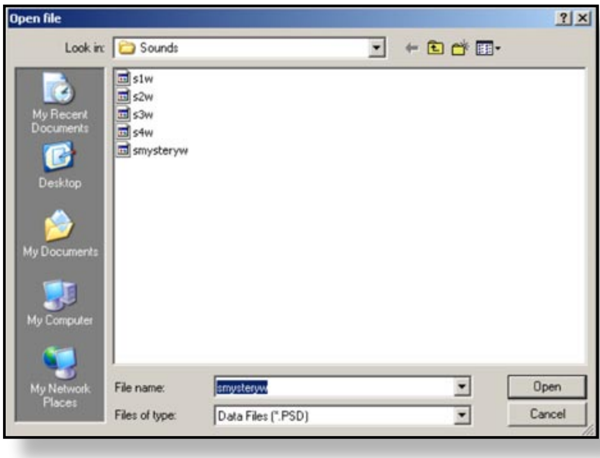
Waveform of a snapped cracker

Activity (i) - Using a microphone to investigate crispness with DrDAQ



'Save file as' box

- If the trace amplitude exceeds the size of the Y-axis on the screen then click the **GO** button again and repeat the snapping slightly further away from the microphone.
- Click on **File** in the Menu bar and then on **Save as** in the drop-down menu that appears. Locate the '**Pico**' folder and then the '**Sounds**' sub-folder. The '**Save file as**' box will then be displayed.

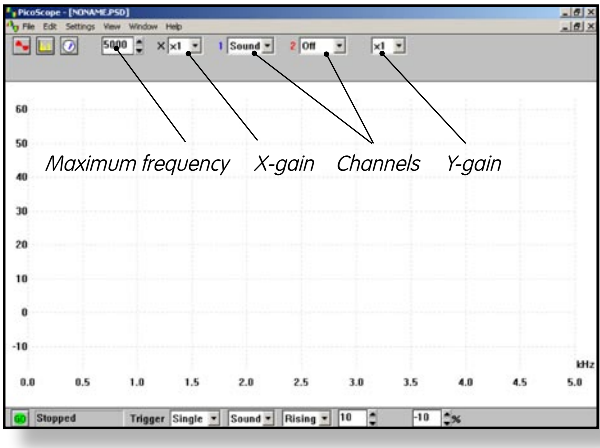


'Open file' box with five files listed.

- Click in the box alongside 'File name' and press the **Backspace** key to delete whatever filename appears and type 's1w' for cracker/wafer 'sample 1 waveform' in its place. Now click the **Save** button to save the sound file for this sample.
- Repeat the operation by first clicking on the **GO** button again and snapping the other cracker/wafer samples available. Give these filenames s2w, s3w, s4w etc. Snap one of the samples again, hiding it from your colleagues, and save this as 'smysteryw'. (Make a note of which sample matches with this file).
- If you have a non-fresh sample snap it and obtain a trace. Save the file with a name such as 's2wold' if it was the same type as one given a filename 's2w' previously.
- To look at and compare these files click **File** in the Menu bar and then **Open** in its drop-down menu to display the '**Open file'** box. Click on the file that you wish to open and then click the **Open** button.

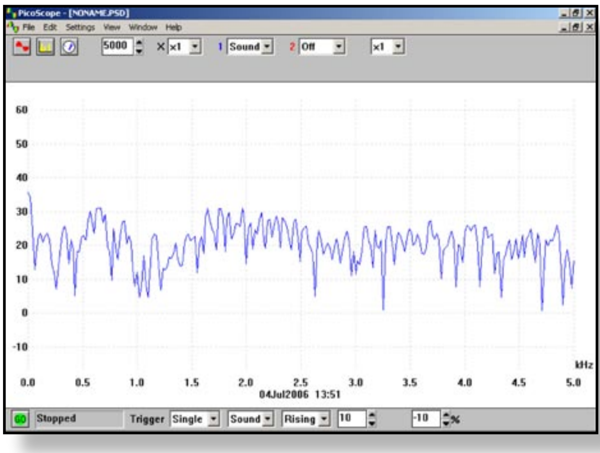
Whilst you might be able to see that each waveform trace is unique to one type of cracker/wafer, this program has an additional feature that can confirm this, it is the **Spectrum Analyser**. This feature displays the intensities of the various frequency components that make up the trace.

Activity (i) - Using a microphone to investigate crispness with DrDAQ



Spectrum Analyser screen

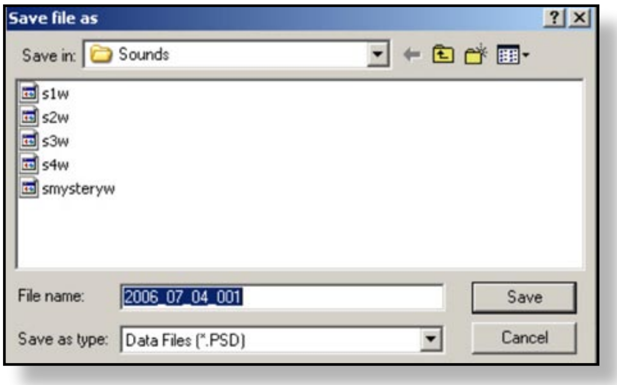
- **To use the Spectrum Analyser you must first close down the Oscilloscope mode by clicking on the lower of the two Xs in the top right-hand corner of the screen.**
- Click on the **Spectrum Analyser** icon to bring up a screen display like the one shown.
- Leave the maximum frequency at 5000 Hz (other Pico virtual instruments can deal with frequencies way beyond 5000 Hz) and the X-gain at x1. Channel 1 should be set to Sound, B to Off and the Y-gain to x1. The Trigger settings you used before should have been retained.



Frequency spectrum of cracker

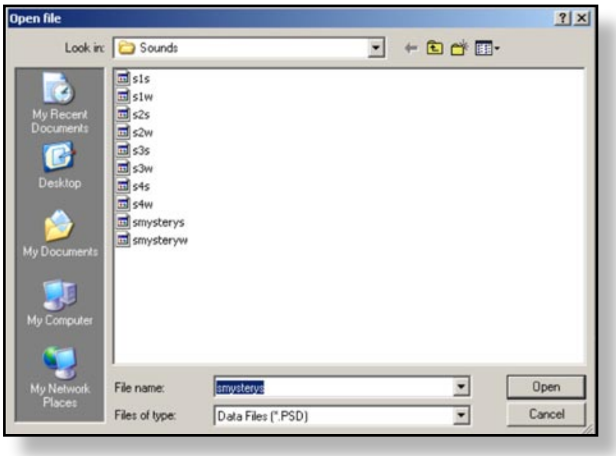
- Click the **GO** button. Snap the first type of cracker/ wafer sample again next to the microphone to reveal the range of frequencies (within 0-5000 Hz on this device) that are produced. A typical frequency spectrum is shown.

Activity (i) - Using a microphone to investigate crispness with DrDAQ



'Save file as' box with five files listed

- Click on **File** in the Menu bar and then on **Save as** in the drop-down menu that appears. The **'Save file as'** box will then be displayed, with the files that you saved earlier.
- Click on the box alongside 'File name' and press the **Backspace** key to delete whatever filename is present and type 's1s' (for sample1spectrum) in its place. Arrange it so that the file is again saved in the 'Sounds' sub-folder of the Pico folder – this should be automatic – and then click the **OK** button. This will save the frequency spectrum sound file for this sample.
- Repeat the operation by clicking the **GO** button again and snapping the other cracker/wafer samples available. Give these the filenames s2s, s3s, s4s etc. As before, repeat snapping one of the samples (the same type as before) and save the file as 'smysterys'.
- If you have a non-fresh sample snap it and obtain a trace. Save the file with a name such as 's2sold' if it was the same type as one given a filename 's2s' previously.



'Open file' box with all files listed

- To look at and compare these files click **File** in the Menu bar and then **Open** in its drop-down menu to display the 'Open file' box as shown. Click on the file that you wish to open and then click the **Open** button.
- Compare the traces of these different samples. See if colleagues can identify which sample had been the 'mystery' sample, and compare the trace of a fresh cracker with that of a non-fresh cracker of the same type.
- To set the computer up for the next user, click **File** in the Menu bar and then Open in its drop-down menu. Now delete each of the saved files by highlighting each og them in turn and pressing the Del(ete) key on the computer keyboard. Click the Yes button in response to the question 'Are you sure you want to send('s1w' etc) to the Recycle Bin?'
- When all the saved files have been deleted, close the **'Open file'** box by clicking on the X in its top right hand corner.

- To finish with the program click on **File** in the Menu bar and then on **Exit** in its drop-down menu.

This type of technique can be used in quality control. Traces from perfect specimens could be compared to traces from samples obtained during production: any major mismatch would identify a problem.

Activity (i) - Using a microphone to investigate crispness with DrDAQ

Questions

How unique were the samples' traces?

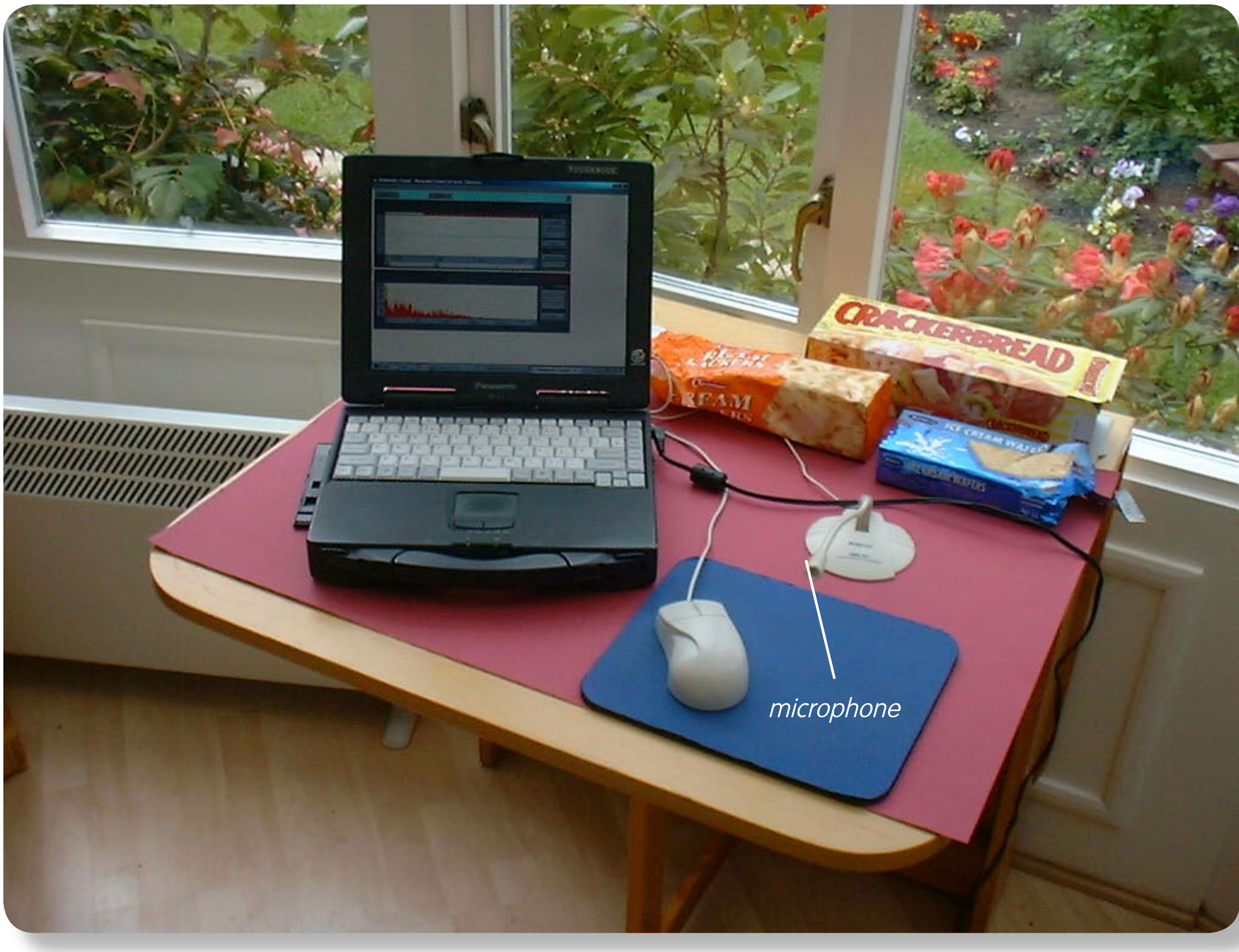
Was the waveform or the frequency spectrum more useful in telling the samples apart?

What difference does lack of freshness make to the traces?

Activity (ii) - Using a microphone to investigate crispness with Multimedia Sound

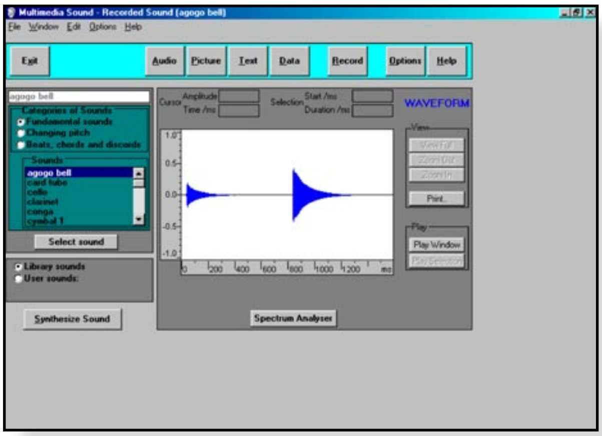
Procedure

With this computer program you can record and display sound files and analyse and display the frequencies within them. This will let you compare a range of sounds.



Computer set up to examine crispness

Activity (ii) - Using a microphone to investigate crispness with Multimedia Sound

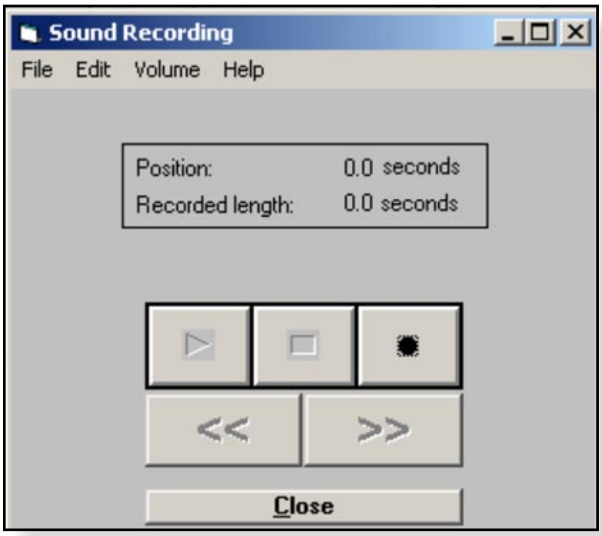


MultiMedia Sound's main screen

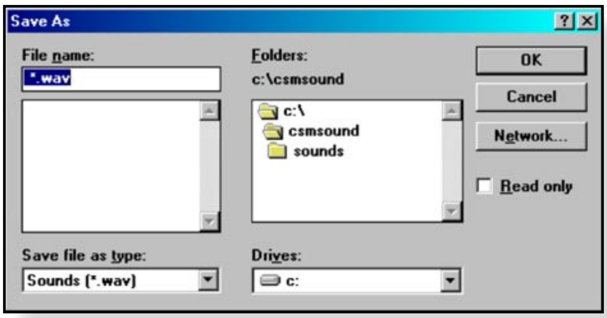
Note: If you are connected via a network you may need to obtain additional instructions.

- Plug in and, where necessary, switch on the microphone. Ensure that this microphone is kept away from the loudspeakers in order to avoid the loud whine of feedback.

- Load Multimedia Sound and then click on the opening screen to obtain the display shown.



'Sound Recording' box

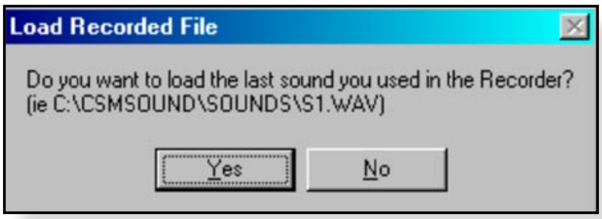


'Save as' box

- Click the **Record** button in the Toolbar to display the **'Sound Recording'** box. Note what the buttons in this box are for.
- Select a cracker/wafer, noting down what variety it is. Click the **Start recording** button in the 'Sound Recording' box and snap the cracker/wafer next to the microphone. Then click the Stop recording button.
- Now click on **File** in the Menu bar of the 'Sound Recording' box and then on **Save as** in the drop-down menu that appears. The 'Save as' box will then be displayed.

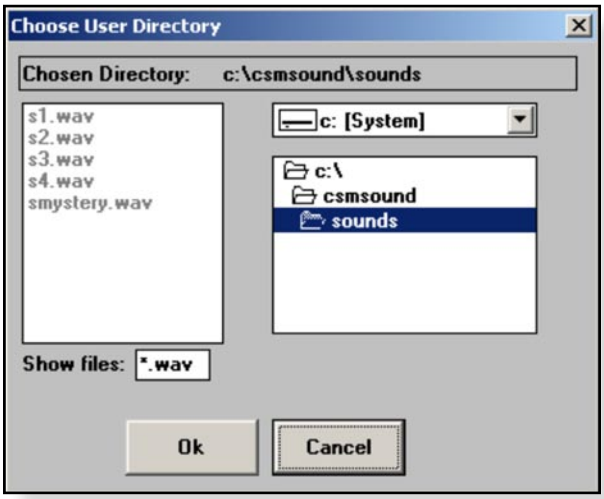
- Press the **Backspace** key to delete the highlighted filename and then type 's1' for 'cracker/wafer sample 1' into this box. Double-click the 'sounds' folder and then click the **OK** button. This will have saved the sound file for this sample.
- Now click on **File** and **New** in the Sound recording box to reset the Sound Recorder.
- Obtain and save files for the other cracker/wafer samples giving them the filenames s2, s3, s4 etc. Note the type of cracker used each time.
- Keeping it out of view, snap one of the criackers again and save it as smystery'.
- If you have been given a non-fresh cracker or wafer, obtain and save a file for it with a name such as 's2old' if it was the same type as that given a filename 's2'.

Activity (ii) - Using a microphone to investigate crispness with Multimedia Sound



Load Recorded File' box

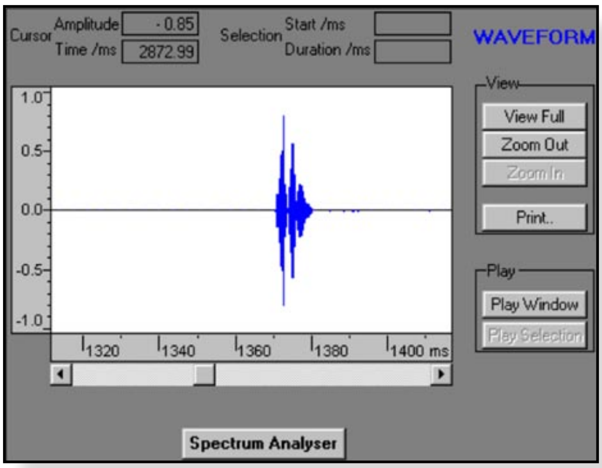
- Now click the **Close** button.You will now see a 'Load Recorded File' box displayed.
- Click the **No** button.



Choose User Directory' box

- Now click the cursor in the white circle at the bottom of the left-hand column alongside 'User sounds' and then on the Set directory button to display the **'Choose User Directory'**.

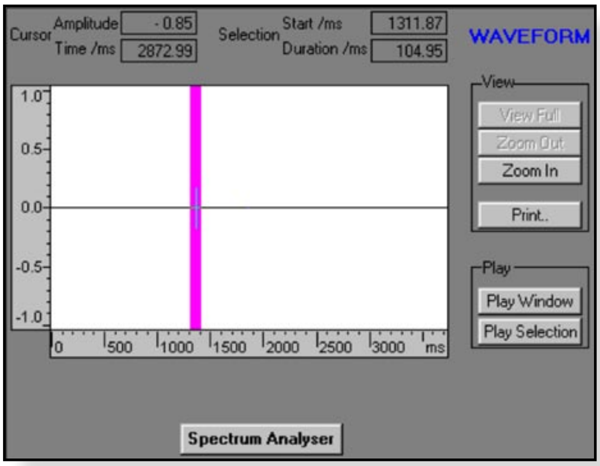
- Now click the **OK** button. Your sample files should now be listed at the top of the left-hand column. Click on the first one to highlight it and then click the **Select sound** button. You should now see the 'Waveform' window as with an unexpanded sound trace displayed.



'Waveform' window with unexpanded sound trace

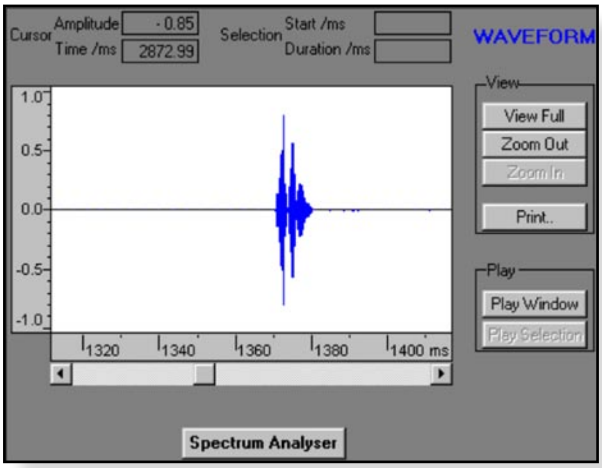
- If you have loudspeakers or headphones available and you now click the **Play Window** button you will hear the snap of your sample again. Repeat with the other samples. You will probably agree that it is difficult to tell the samples apart from the sounds of their snapping alone. However, this program allows you to look in detail at the waveforms produced by each sample.

Activity (ii) - Using a microphone to investigate crispness with Multimedia Sound



Dragged cursor highlighting unexpanded sound trace

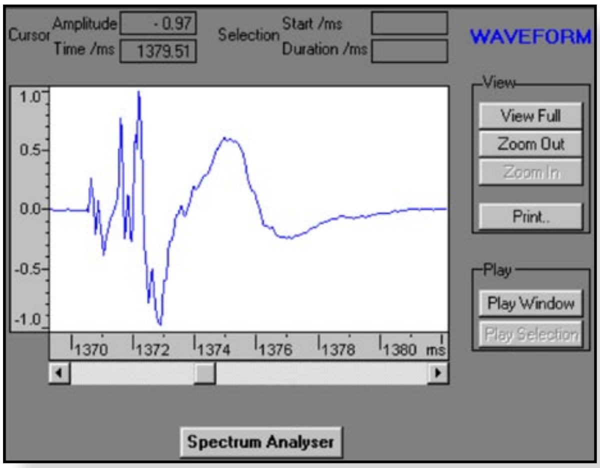
- Select and display the sound file of your first sample again. Now move the cursor to just to the left of the unexpanded sound trace, hold down the left mouse button and drag the cursor to just a little to the right of the trace and release. A section of the trace will be highlighted as shown.



Expanded sound trace

- Click on the **Zoom In** button to obtain the expanded sound trace.

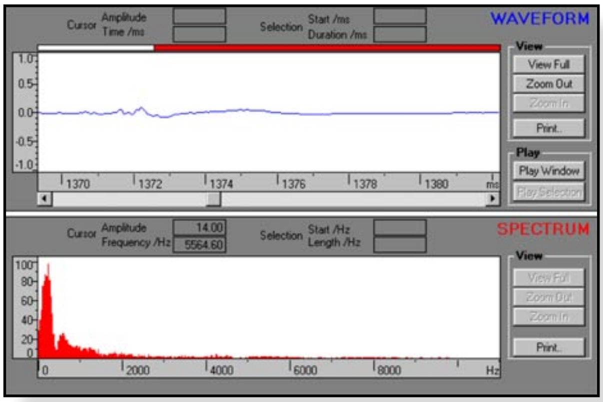
Activity (ii) - Using a microphone to investigate crispness with Multimedia Sound



Further expanded sound trace

- This waveform trace can be expanded still further, as shown, by holding down the left mouse button whilst dragging the cursor from just to the left of the trace to just to the right of it, releasing the left mouse button and then clicking the **Zoom In** button.

Whilst you might be able to see that this waveform trace is unique to one type of cracker/wafer, this program has an additional feature that can confirm this: it is a **Spectrum Analyser**. This feature displays the intensities of the various frequency components that make up the trace.



Waveform and Frequency Spectrum

- Click the **Spectrum Analyser** button to display the additional frequency spectrum of the trace.
- Click the **Close** button to return to the previous screen and repeat the spectrum analysis with the other samples' traces.
- See if your colleagues can identify the Mystery cracker/wafer, and ,if successful, whether the Waveform of the Frequency Spectrum trace was better for identifying it.
- You could also compare the trace of a fresh cracker with that of a non-fresh cracker of the same type.

To finish with the program click the **Exit** button and respond '**Yes**' to the question 'Do you really want to exit this application?' .

To set the computer up for the next user, use Windows Explorer to locate the 'csmsound' folder and its 'sounds' sub-folder. Open the 'sounds' sub-folder and delete the files that you had saved.

This type of technique can be used in quality control. Traces from perfect specimens could be compared to traces from samples obtained during production: any major mismatch would identify a problem.

Activity (ii) - Using a microphone to investigate crispness with Multimedia Sound

Questions

How unique were the samples' traces?

Was the waveform or the frequency spectrum more useful in telling the samples apart?

What difference does lack of freshness make to the traces?