

Principle and Construction of the Sound Box

Description of circuit

The sound box produces an audible sound with a frequency which is dependent on the conductance of the device or material connected between the probe leads. The better the conductance of the sample under investigation the higher the pitch of sound produced. Of all the senses hearing is the one that provides the best quantifiable discrimination of the appropriate stimuli, in this case frequency. It is hence relatively easy for children to 'hear' the change in conductance as the sample is changed from a good conductor (a metal), through a reasonable conductor (water), a poor conductor (the human body) to an insulator (plastics). In the latter case the box produces no sound.

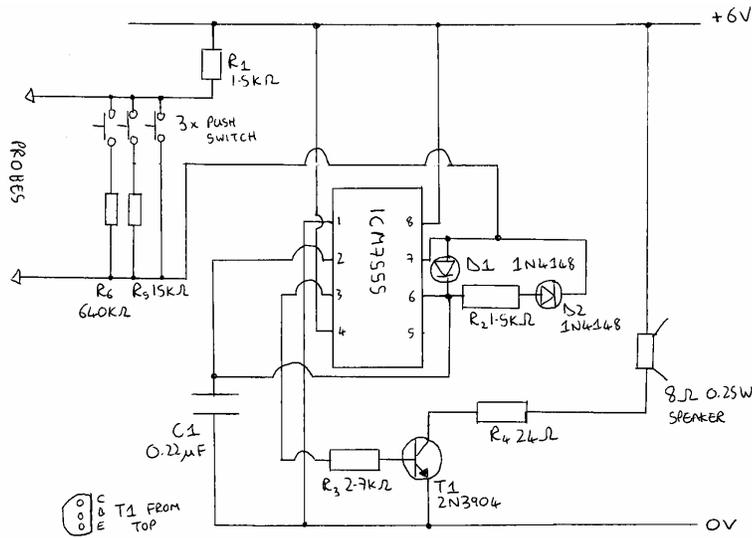


Figure 1. Circuit diagram.

The circuit is based on the CMOS version of the 555 timer integrated circuit which can be configured to act as an oscillator. The basic circuit diagram is shown in Figure 1. For this configuration the frequency of the oscillator is given by the equation

$$f = \frac{1.46}{(R_1 + R_2 + R_X)C}$$

where R_X is the value of the resistor connected between the external probes. f varies between $\sim 2\text{kHz}$ when the probes are connected to a good conductor (e.g. a length of copper wire) to $< 1\text{Hz}$ for a poor conductor (e.g. lightly touching the probes with dry hands).

The three push switches introduce three different resistances between the probes and allow the operation of the box to be demonstrated before any samples are connected directly to the probes. These could be omitted if desired but seem to be worthwhile.

The two diodes keep the 'mark' length of the oscillations a constant length and only the 'space' part changes as R_X varies. This seems to provide a sharper 'click' from the speaker at low frequencies and also reduces the average current consumption of the circuit.

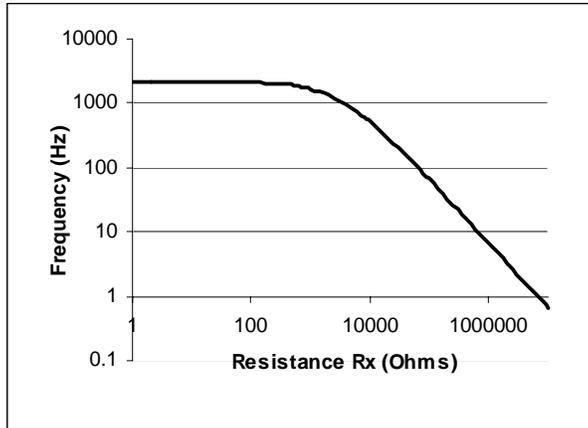


Figure 2. Frequency vs resistance response of the Sound Box

For the values of R_1 , R_2 and C indicated in Figure 1 the frequency of the circuit as a function of R_X is plotted in Figure 2.

Because of the need to include resistors R_1 and R_2 , the circuit is not sensitive to changes in R_X over the range 0~300 Ω . Hence it is not possible to compare the conductance of different metals as these have relatively little variation. However the circuit does produce a wide range of frequencies when used to study a number of common materials. For example lightly touching the probes gives a resistance ~10M Ω and a frequency below 1Hz, holding the probes firmly decreases the resistance to ~1M Ω and increases the frequency to ~7Hz, and wet fingers decrease the resistance further to ~250k Ω and give a frequency 30Hz. These changes can be easily 'heard' by the audience. In addition the circuit gives a noticeable response to the change in conductance of water when a small amount of salt is added and also the changes in resistance of a thermistor when warmed by bodily contact or a light dependent resistor when exposed to different levels of light.

Options

It is possible to include an additional switch so that the value of the capacitor can be changed. In the prototype a second capacitor with a value of 0.022 μ F was included which, for an equal value of R_X , gives a frequency x10 higher than is obtained with the standard 0.22 μ F capacitor. This effectively increases the sensitivity to very large values of R_X . With this increased sensitivity it is possible to investigate the resistance of a line drawn on a piece of paper with a soft graphite pencil and to show that resistance increases with the length of the line but decreases with increasing width. This is not something that we have investigated in detail.

Cost

If you have access to basic materials (including insulated stranded wire, tinned copper wire, copper clad strip board, solder, glue etc) and tools (soldering iron, drills etc) then the sound box is relatively cheap to construct. The electronic components, switches, speaker etc cost ~£13.00. On top of this the thermistor and light dependent resistor add another ~£1.50. However if you have to buy everything then the total price will be higher. Construction time is ~4 hours.

Construction

The parts required to construct the sound box are listed at the end of this document. They are all available from Maplin Electronics and the corresponding part numbers are given along with price (as of August 2005).

Start by cutting the required holes in the lid of the box. The box is the most expensive item so money could be saved by using an existing box (e.g. a food container). Holes are required for the speaker (an array of small holes looks nice), the on/off switch, the three push switches and the switch to change the capacitor value (if required). The holes can be drilled more accurately if first a small (1~1.5mm diameter) drill is used following which they are opened out with a larger size drill. If you use the recommended slide switch for the on/off switch then you will need to drill and file out a suitable rectangular slot plus two small holes to fix this switch in place. A toggle switch (requiring a single round hole) would be easier to fit but is more prone to accidental switching. A hole also needs to be drilled in the end of the main part of the box for the probe wires.

Next fix the speaker in place using Evostick or a suitable glue. The on/off switch could also be glued in place which will save drilling two of the holes and the need for the two small nuts and bolts. Also mount the three push switches (you may need to remove the washers if the lid of the box is relatively thick). Next solder suitable lengths of insulated, flexible multicore wire to the speakers and switches. One side of the three push switches can be connected together using a suitable length of tinned copper wire. Next cut a suitable size piece of the copper clad strip board from a larger piece. This is possible by scoring carefully a few times with a sharp knife and then flexing the board along the scored line. The recommended box has a series of vertical grooves into which the board can be slid if it is of the correct width. Otherwise the board can be stuck to the side or bottom of the box with a double sided sticky pad or fixed more firmly with a nut and bolt and holes drilled through the board and the box. The layout of the circuit board is not critical, Figure 4 shows a possible configuration.

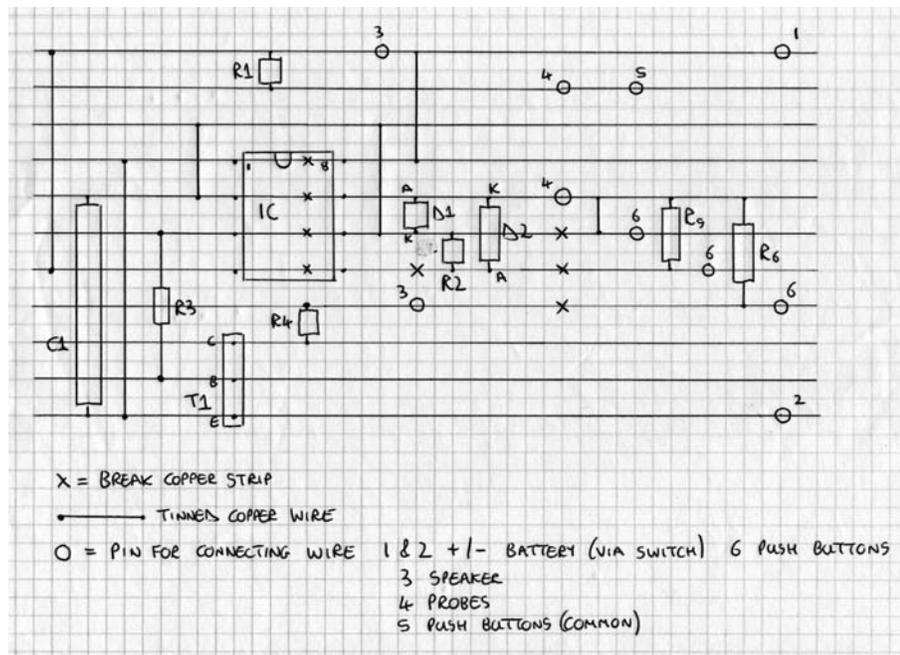


Figure 3. Suggested circuit board layout.

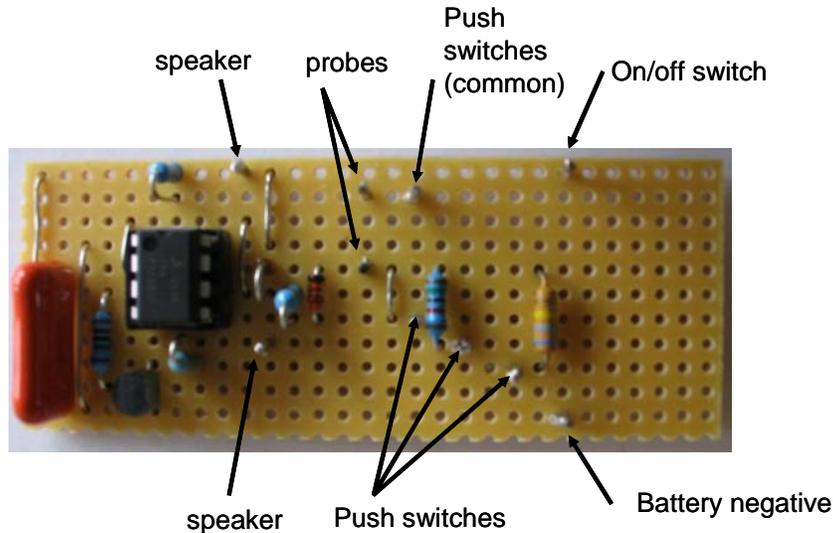


Figure 4. The completed circuit board. The labels refer to the connecting pins.

It is advisable to use a socket for the IC but all other components can be soldered directly to the board. Use tinned copper wire to join different points on the board. Some of the tracks will need to be broken at various points (e.g. under the IC), this can be achieved using a specialised track cutter or with a suitable sized drill. Although the leads from the speaker and switches can be soldered directly to the board it is more convenient to first solder connection pins to the board and then to solder the leads to these pins.

Once the board has been completed the IC can be inserted. This is a CMOS component and so can potentially be damaged by static electricity. It is hence recommended that the device is not handled when working on a nylon carpet or wearing nylon clothes (particularly in a dry atmosphere). However in practise it appears difficult to damage these devices, although it is sensible to touch an earthed object before handling it. Figure 4 shows the component side of the completed circuit board. Figure 5 shows the reverse side with the copper strips.

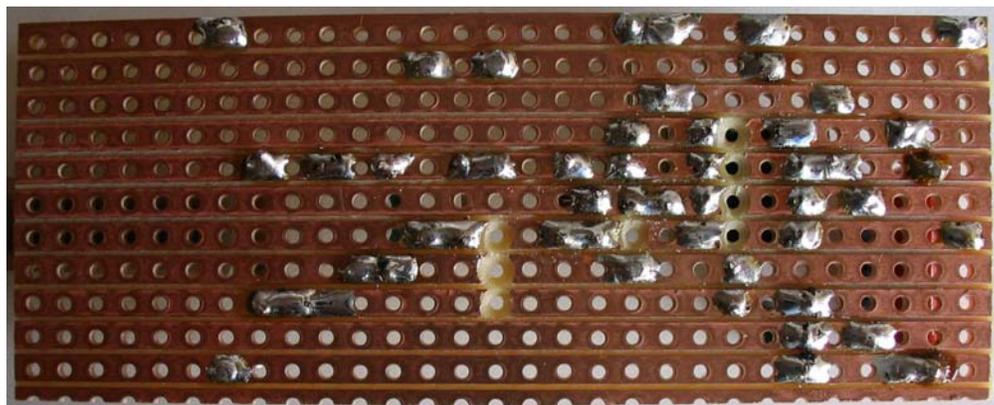


Figure 5. Reverse side of the completed circuit board.

Finally insert the batteries into their holder, attach the battery holder to the battery clip and switch on. Pressing one of the three buttons should produce an audible tone. Holding the probe leads firmly should produce a tone of a few Hz. The circuit board

and batteries can be placed in the box, the probe leads fed through the hole in the box and the crocodile leads soldered to the ends of the probe leads. The lid of the box can be labelled using rub-down transfers or labels can be printed and stuck in place with invisible tape. The finished box is shown in Figure 6.



Figure 6. External view of the completed box

Fault finding

If the box does not work check that all the components have been connected together correctly and check the polarity of the IC, the two diodes and the transistor. Check that the solder has flown freely around all of the joints (it should have a bright colour) and that solder has not inadvertently flown between neighbouring copper tracks. Make sure the all of the track has been broken where intended as it is easy to leave a thin piece of copper remaining at one side of the hole. A hand lens or magnifying glass is useful for looking for some of these faults.

Construction of optional parts

If you plan to use the thermistor and/or light dependent resistor it is best to solder these to a small piece of the copper clad board as the leads of these components are very thin and are likely to quickly break. Raise them slightly from the surface of the board, to prevent overheating when soldering, by slipping a short length of plastic insulation (stripped from a length of the multicore connecting wire) over the leads. Two connection pins can be soldered to the board to allow it to be attached to the crocodile clips of the probe leads. Figure 7 shows the light dependent resistor and thermistor mounted on the copper strip board.

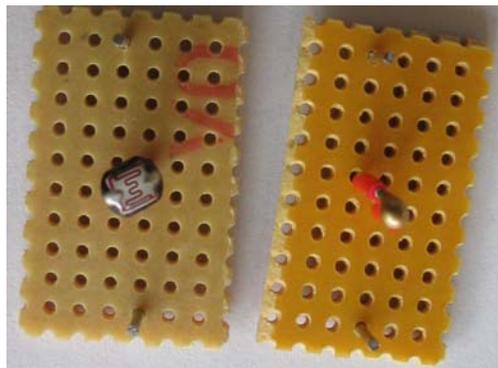


Figure 7. The light dependent resistor and thermistor mounted on small circuit boards.

If you plan to study the conductivity of liquids then suitable probes can be constructed by unbending two large paper clips and gluing these into suitable sized holes drilled into a short length of wood. The crocodile clips can be clipped to the upper ends of the wires with the lower ends immersed into a beaker of liquid. You may need to experiment with the length of wire which is immersed in the liquid to achieve a frequency which changes noticeably when salt is added. Figure 8 shows the construction of the liquid probe.

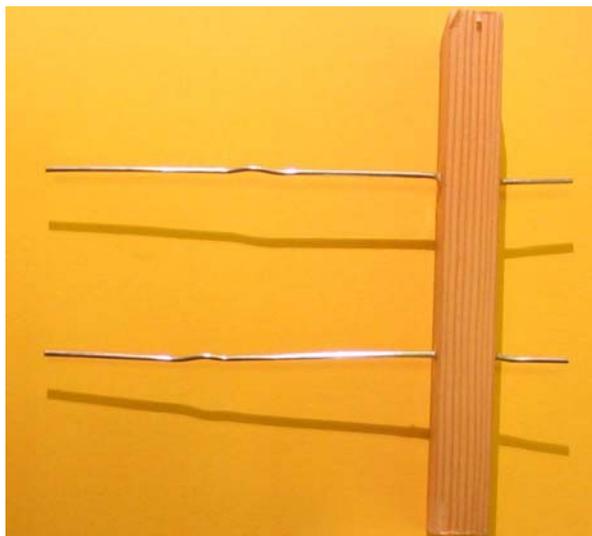


Figure 8. The liquid probe.

List of required parts

Description (and number)	Maplin code	cost
ICM7555IPA CMOS timer IC	YH63T	0.99
8 pin DIL IC socket	BL17T	0.14
2N3904 transistor	QR40T	0.09
1N4148 diode (x2)	QL80B	0.16
56mm diameter mylar speaker	VC85G	1.99
1.5k Ω resistor	M1K5	0.07
2.7k Ω resistor	M2K7	0.07
24 Ω resistor	M24R	0.07
0.22 μ F polyester capacitor	BX78K	0.34
4AA battery box	HF29G	0.49
PP3 battery clip	HF28F	0.29
Pack of 4 AA batteries	L43AL	1.99
Sub miniature red push switch (x3)	JM47B	1.47
Sub miniature slide switch	FH35Q	0.49
General purpose ABS box (150x80x46mm ³)	N72BQ	3.49
Crocodile clips	FS51F	0.98
Total cost		£13.12
Options		
Light dependent resistor 77k Ω -340k Ω	N49AY	0.99
Thermistor 15k Ω	FX22Y	0.49
Sub miniature slide switch	FH35Q	0.49
0.022 μ F polyester capacitor	BX72P	0.12
You may also need		
Copper strip board 3962	JP50E	2.79
Connection pins 2145 (pack of 100)	FL24B	2.99
Solder	N29AR	2.49
Tinned copper wire 24 swg	BL15R	1.19
Plastic insulated wire (internal to box)	BL56L	1.49
Plastic insulated wire for probes (green)	BA38R	1.39
8BA nuts and bolts for slide switches		
Glue		
Tools		
Various size drills		
Small files		
Soldering iron		
Wire cutters		
knife		