CHAPTER 16

Sound, Music and Audio Technology

16.1 INTRODUCTION

What is sound? One frequently-played TV advertisement for a popular drink showed people whistling and causing glasses and bottles to shatter. A measure of greatness of singers is that they have the ability to shatter crystal glasses by reaching a certain high-pitched note. The renowned opera singer Maria Callas (1923–77) was reputed to be able to do this.

- Why does this happen? Does it happen or is it one of those exaggerated myths?

After completing this chapter you will be able to answer this question and others such as these:

- Can you hear space ships explode in space?
- How is sound used by dentists, doctors, bats, the blind, and fishermen?
- Why do you hear a siren differently as a police car comes toward you and goes away? How does an understanding of this allow you to measure the speed of a cricket ball?
- Why can you hear so well in the 'bush' at night?
- Do you know how insects can hear bats? Can any animal 'jam' a bat's sonar?

16.2 WHAT IS SOUND AND HOW IS IT PRODUCED?

In Chapter 13 we suggested that if a tuning fork is tapped and held beside another one of the same frequency, the second fork also begins to vibrate. Sound waves also cause our ear drums to vibrate and microphones to produce small alternating voltages.

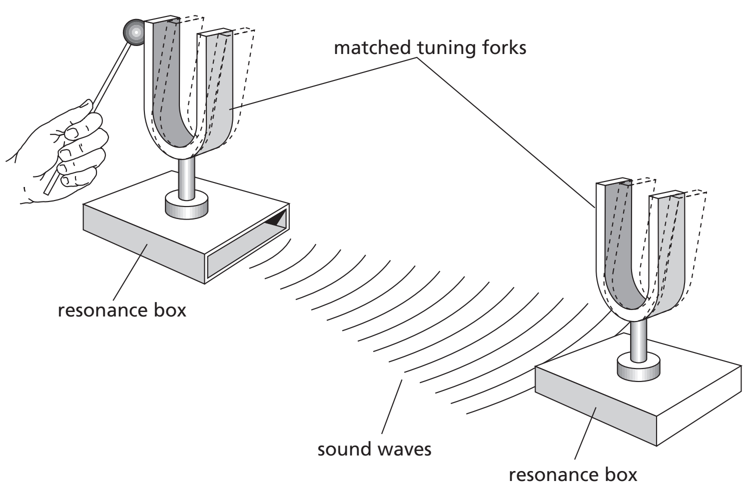


Figure 16.1
One vibrating tuning fork will cause another close by to vibrate.

Sound is a form of energy — one that travels from the source to the receiver by means of waves. In Chapter 13 it was indicated that sound waves were longitudinal mechanical waves — waves that require a medium for transmission.

EI Activity 16.1 SOUND ENERGY

Research an area that supports the proposition that sound is a form of energy, and be prepared to explain your evidence to the class.

EI Activity 16.2 SOUND IN A VACUUM

If your school possesses a vacuum pump, the following demonstration should indicate that sound requires a medium for its propagation.

1 Place a ringing electric bell in a bell jar and extract the air from the jar using the vacuum pump.

2 What do you notice as the amount of air in the jar is reduced?

3 Predict what you would notice if the air pressure was increased.

EI Activity 16.3 SOUND VIBRATIONS

Part A

1 Place a metal ruler on a desk with about three-quarters of its length overhanging the edge of the desk. Pull the overhanging end down and let it vibrate.

2 What happens? What do you hear?

3 Place your ear on the desk and you will hear the sound with astonishing clarity.

4 What do you notice when you rest the bone behind your ear on the desk?

5 As the ruler is vibrating move it in so less overhangs. What do you hear now?

6 What happens if you use a softer surface?

Part B

It is not easy to see a tuning fork vibrating but it can be felt. Touch the stem to your lips, your teeth, your head. Touch the prongs on to the surface of water. What do you notice?

Photo 16.1
Siren disc.

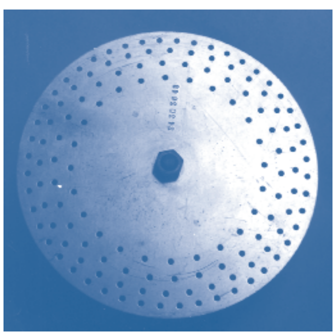
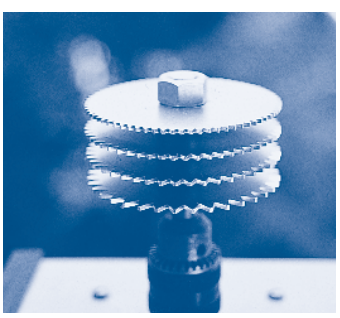


Photo 16.2
Savart's disc.



It can easily be seen that the vibrations cause the sound. Music students in the class may be able to tell you why guitars, flutes or trombones produce sound. Sound is produced by something vibrating — a string, a reed or an air column. The different sounds are produced by the different frequencies of vibrations. This can be shown by tapping two tuning forks of different frequencies. They produce different sounds due to the different rates of vibration of the arms of the forks.

We speak and hear due to the vibration of membranes. The vocal cords in our throats vibrate at different rates to produce sounds. The tension of the vocal cords controls the rate of vibrations. The energy carried by the sound waves causes the ear drum to vibrate. These vibrations are transposed into discernible noises by the brain. When you get a throat infection your vocal cords become inflamed and swollen. This gives you a husky voice.

Sound is a form of energy produced by the vibrations of objects and carried by longitudinal mechanical waves.

A siren disc (see Photo 16.1) has concentric circles of holes in an aluminium disk. When it is spun at high speed and air blown through the holes, the chopped jet of air produces a sound wave.

Savart's toothed wheel can also be used to produce 'musical' sounds. By holding a piece of card against the spinning toothed wheel, different frequencies can be produced. The number of teeth per wheel are in a set ratio and, when sounded at the right speed, produce what music students call the notes of the major triad: C_4, E_4, G_4, and C_5.

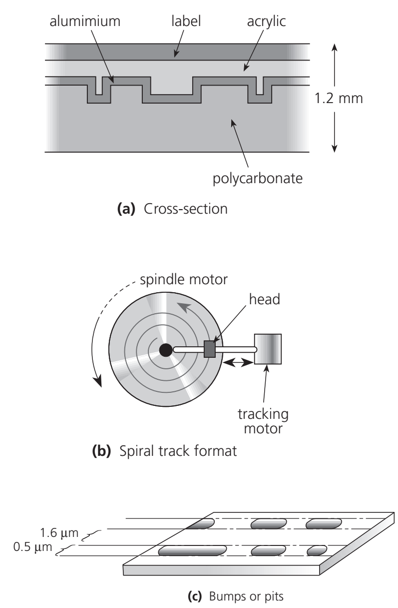
Modern speaker driver research is concentrating on the materials that make the magnet assembly. Australian CSIRO researchers are among the world's leaders, producing exotic magnetic alloys that provide very strong magnetic field densities. This enables speakers of high power-handling capability to be made smaller and smaller. A visit to the local hi-fi component retailer will confirm the incredibly small size of some modern speakers for the sound output they provide.

Speaker drivers are often designed to reproduce only a small part of the audio spectrum efficiently (from 20 Hz to 20 kHz); so when used in combination they need to be separated with electronic cross-over networks involving capacitor–inductor frequency filters. Some interesting names are given to various frequency component speaker drivers. For example, the **Subwoofer** is the high-power driver used to reproduce low-frequency effects, LFE signals such as explosions and deep bass music notes, usually below about 150 Hz. These are usually housed in large boxes. **Woofers** are used to reproduce low to mid-range frequencies up to about 1.0 kHz. **Squawkers or mid-range** drivers can handle a wide range of frequencies in the audio spectrum and are often used as the centre speech-reproducing driver, typically from several hundred hertz to about 50 kHz. **Tweeters** are the specialist high-frequency drivers that reproduce top-end sounds such as hisses and chirps from several thousand hertz right up to 20 kHz. Often they only need to be quite low in output power as the large amount of air movement is not necessary.

A well-designed speaker system may contain multiple drivers, with woofer–squawker–tweeter in the one box cabinet, and be able to handle simply one output channel from the amplifier. Speaker resistance or impedance to the flow of AC electric current is measured in ohms. Typical home theatre speaker systems are rated at 8 ohms, while typical car audio speaker systems may be rated at only 4 ohms.

The home theatre digital sound revolution

Figure 16.18
A compact disc.



Audiophiles of the past usually raved over their quadraphonic or stereophonic systems, which normally consisted of analog components such as amplifier, record player, AM–FM radio receiver, and one or more magnetic tape decks. This was usually coupled with an inefficient stereo left–right speaker system which, if the system was a good one, reproduced original music with minimal distortion and noise levels. With the coming of the digital revolution, audio and videophiles now have components such as digital AM–FM stereo PLL (phase locked loop) tuners, CD and DVD players, hi-fi stereo video recorders and DAT (digital audiotape) decks coupled with HD (high-definition) digital televisions, multi-channel and decoder amplifiers, which reproduce audio and video with incredible fidelity and without discernible electronic noise. The computer revolution has allowed this equipment to be used with ease to produce audio and video source material in the home without serious sound studios.

Let's now take a look some of the technology behind this digital audio–video revolution and find out how it works. The process of analog to digital conversion, which underlies this technology, is discussed in Chapter 24 (Section 24.2).

AM–FM radio tuners A radio tuner will receive transmitted amplitude or frequency modulated waves from a local radio station, usually in stereo (tuning principles are discussed in Chapter 31) and convert small microvolt signals into a form ready to be amplified.

Cassette or digital audio tape decks These contain electromagnetic induction heads that decode magnetic patterns stored on magnetic tape and convert them into an electronic signal stream, again allowing amplification.

Audio compact discs (CDs) An audio music (CD-DA format) or computer data (CD-ROM format) device is a simple injection-moulded circular disc of polycarbonate plastic about 12 cm in diameter and about 1.2 mm thick, onto which is evaporated a thin layer of reflective aluminium. This is then covered with a layer of acrylic for protection and marketing labels are attached to the top of the acrylic layer. When the CD is recorded or written to by a laser beam, small indentations that represent the 1s and 0s encoded digital bitstream are made into the reflective aluminium–plastic layer. (Refer to Figure 16.18, which of course is not to scale.) These indentations become raised bumps when read from the scanning pickup laser head side of the disc.

The track written onto a CD is one long continuous spiral 0.5 µm wide (1 µm = 1×10^{-6} m), laid down with separations of only about 1.5 µm. Typical data bumps on the track are at least 0.83 µm long and 126 nm high (1 nm = 1×10^{-9} m). For a typical 700 MB CD the recording track may be about 5.0 km in total length. The CD player has the difficult job of reading the data track and has four major functions to perform:

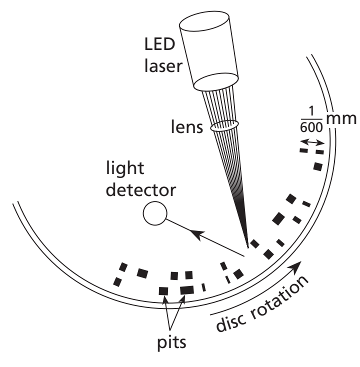
1 *The drive or spindle motor* must spin the disc at different speeds depending on what part of the data track is being read. Speeds of between 200 and 500 rpm are common, but CD-ROM discs in a computer drive may spin even more quickly.

2 *The tracking motor* moves the laser head linearly over the disc surface from inside to outside. The tracking motor position also determines the spindle motor speed because the reflective bumps towards the outer rim of the CD will be travelling more rapidly past the pickup head, and the spindle motor has to be slowed down so that data comes off the disc at a constant rate.

3 *The lens and laser assembly*. This is why all drives have the LASER CLASS device warning symbol attached to them, but in reality they are not dangerous at all when used normally. The lens system must focus the laser beam onto the lands and bumps of reflective aluminium. The laser beam passes through the polycarbonate layer and reflects off the bumps and lands, producing a variable light signal to the opto-electronic sensor. Further electronic digital gates in the drive provide the digital bitstream to the DAC and finally to the internal signal amplifier. Figures 16.19 and 16.20 show these processes.

4 *The error-correcting and subcode-data-reading electronics.* This system monitors any laser head misreads due to dust or scratches on the disc surface (called burst errors) and allows the bitstream to be recovered. The subcode data encodes position information on the disc so that operations like finding and skipping to a particular music track can be accomplished. These systems are most important on a computer data CD-ROM. Can you see why?

Figure 16.19
CDs contain pits that result in the interference of light to produce electrical currents.



tracks on a digital disc

It is interesting to further consider the differences between a normal CD and the recordable or writable **CD-R** format, or even the rewritable **CD-RW** format. Engineers are constantly improving the capabilities of these digital formats and player-readers. Figure 16.18 shows the layers of a normal CD. In the CD-R format there are no bumps or lands, just a smooth reflective aluminium layer that rests on top of a layer of photosensitive dye. On a blank CD-R disc this dye layer is translucent, but when the burner laser heats it up the dye becomes opaque. The data track thus becomes a series of dark and reflective spots. One disadvantage of this is that, once burnt, the CD-R layers are permanent.

To produce the re-recordable CD-RW format disc even more layers are required. Sitting below the aluminium layer is a special chemical layer containing a crystalline phase-changing compound of metallic alloy. Under normal conditions this compound's form is crystalline and translucent, but again if the burner write laser heats it above 600°C for an instant it melts and becomes amorphous and opaque even after it is cooled. This process allows the digital bitstream to be encoded as before. The CD-RW drive also contains an erase laser setting that can hold the phase-change layer long enough at its melting temperature to allow the compound to revert to its translucent state, thus allowing data to be rewritten over and over again.

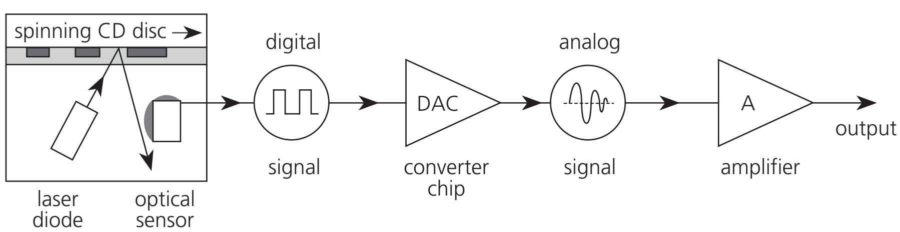


Figure 16.20
Schematic diagram of CD player electronics.