



## EARPHONE LIMITERS - QUESTIONS AND ANSWERS

### Can earphones really damage your hearing?

Compared to giant PA stacks and studio monitors with 15" drivers, earphones look small and harmless. But the effect on your ears depends only on how much the sound makes your eardrums vibrate. Earphones are of course very close to the ear, and some types couple efficiently into the ear canal. In fact, most earphones can produce a louder sound at the eardrum than all but the largest and most powerful studio monitors and can easily give noise exposures well above the accepted safety limits.

Unfortunately there are a couple of extra danger factors that make it even more necessary to take care with high sound levels from earphones.

Firstly, there is a well known psycho acoustic effect that earphones don't sound as loud as loudspeakers when the sound level at the eardrum is the same. This may happen because even with hi fi earphones the brain isn't totally fooled into thinking the sound is "out there", it can work out that the music is right next to your head and so expects it to sound loud. To match loudspeakers subjectively, the amount that earphone level has to be turned up varies between individuals but is typically 6dB, equivalent to four times the sound power.

Secondly, earphone listening is private. With loudspeakers, if you listen at a very high level, it will usually be obvious eventually the neighbours will complain! With earphones, people can get an excessive dose without themselves or anyone else realising it.

### Are speech and music different from industrial noise?

Many people find it difficult to believe that listening to music can be a hazard to hearing. However, there's little evidence that music, however harmonious, is actually safer than unpleasant noise that would measure the same on a sound level meter. Even those who argue that music is safer than other noises would agree that if it is loud enough, and repeated often enough, music can damage hearing.

So far as the law protecting people at work is concerned, loud music is just another hazardous noise. So, when people are working with reproduced sound, safety must be taken seriously.

Not only music, but speech on earphones can in some situations give an excessive noise dose. This can happen where people such as telephone operators listen for long periods every day. Another particularly difficult situation is where people need to understand speech with high levels of background noise. In this case it is vital to use good noise excluding earphones, but even when using such, you must guard against excessive noise exposure.

### What is the law about high sound levels?

In EU countries, the law protecting people at work from high sound levels is based on the 1986 EU Council Directive 86/188. Each EU country has translated this directive into its own law. In the UK this is done by the Noise at Work Regulations (1989).

This law is based mainly on the concept of a daily noise "exposure". A loud sound for a short period, or a not so loud sound for a longer period, can both give the same exposure. If the sound level is steady and the working day is eight hours, the exposure is numerically the same as the sound level for example, a production line worker, on an eight hour shift, in a factory with a steady noise level of 95dB(A), would have a daily exposure of 95dB. If the sound level varies, the exposure must be measured with an integrating sound level meter.

There are two levels of exposure at which specific action must be taken, the first action level of 85dB and the second action level of 90dB. When the first action level is reached, employers must give their employees information and training and offer them ear protection, (for example, earplugs), but the employees don't have to wear the protection if they don't want to. However, when the second action level is reached, the employees would be breaking the law if they don't wear ear protection and, the employer must also do what they can to reduce the noise level.

Of course, some sounds such as close gunfire can cause damage almost instantaneously, so the regulations also limit the instantaneous maximum sound that people can be exposed to. Luckily music on earphones is extremely unlikely to reach this level<sup>1</sup>, although it is not impossible under fault conditions which could apply a high voltage to the earphones.



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Most developed countries have some form of law to control sound levels at work, usually based on an exposure limit of 85dB or 90dB. In the US, the OSHA sets a 90dB limit, but it is calculated differently from the EU limit and when the exposure time is short it allows higher sound levels than in the EU.

Those with responsibility for people exposed to high sound levels should check the law in their own country. Even within the EU there are variations. For example, in most EU countries, employers have to provide audiometry to people with high noise exposure.

### How do you measure sound level from earphones?

If you tried to measure the sound level from earphones with an ordinary sound level meter, you could get very different answers depending on exactly where you put the microphone and possibly none of them would be right!

The output of electrical signal sources depends on both their source impedance and the load impedance. Similarly, acoustic sources have an acoustic source impedance, and to measure them correctly they must be connected to the correct load impedance. For earphones, that is an ear! Real ears vary between individuals, so in practice we use a standard artificial ear known as a coupler<sup>2</sup>. This incorporates a microphone, placed to measure the sound level in a position corresponding to the eardrum on a real ear. The coupler replicates only the part of the ear from the end of the ear canal inwards. This is enough for insert earphones, but headphones also need the outer ear and head surface. For these, the most practical solution is to use the coupler together with the head part of an acoustic manikin, commonly known as a "dummy head". The dummy can then "wear" headphones just like a real person.

Even this measurement needs to be corrected. The production line worker, standing in the steady 95dB(A) factory noise would probably have a much higher level at his eardrum, depending on the frequency of the sound, possibly 105dB(A) or even more. This is because the outer ear and ear canal act as an efficient collector and amplifier of sound. For a fair comparison between sound from earphones and sound measured in rooms we must correct by subtracting a frequency dependent factor from the measured level. This finally gives a figure that can be correctly compared with sound levels measured in the usual way.

The specified levels on earphone limiter sets supplied by Canford are measured in this way. These levels cannot be measured with a standard sound level meter.

### What are the BBC earphone sound level limiters?

When each earphone or headphone has its own limiter, whatever equipment it is plugged into the sound level will be controlled. The BBC which has a large and constantly changing variety of equipment with jack sockets, decided long ago that they would control earphone sound levels in this way and designed limiters for the purpose. These BBC designed limiters are now supplied by Canford Audio. The three current designs, each catering for a range of earphone sensitivities and impedances, are implemented as thick film hybrid circuits. The limiters fit in small plastic boxes which are connected in line in the headphone lead.

Canford have now modified the BBC design to fit inside the earpiece of the Sennheiser HD480II headphone and other popular broadcast use headphones, making a stronger and more tamper proof alternative.

The limiters are adapted for different types of earphones by cutting internal links, or by adjusting a potentiometer in the case of the low impedance high sensitivity version. The circuits are driven entirely by the signal and use no battery or external power, so fitting a limiter has some effect on both the sensitivity and the impedance of the earphones. Most types of earphones can be accommodated, but there are a few models where it is not possible to achieve an acceptable compromise between limiting level, sensitivity and impedance.

Limiters should not be fitted or adjusted without specialist knowledge and suitable acoustic test equipment. Every headphone limiter set sold by Canford is individually tested on an acoustic jig to check that the limiting level is within tolerance.

Note that broadcast or sound recording limiters are usually designed to compress the dynamic range without audible distortion, but protection limiters are very different and are designed so that excessive energy cannot pass to the earphone. The aim is to set the volume so that the limiter does not operate!



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### How do you decide on the limiting level?

People sometimes ask why, when the first action level of the Noise at Work Regulations is 85dB, are earphone limiters often set at 93dB(A), and sometimes even higher?

Remember that the Regulations are based on exposure to steady noise for an eight hour day. Music and speech vary in level, and very few people at work listen on earphones for their whole working day. So, the average level, (which controls the legally defined exposure), will usually be quite a lot less than the maximum level controlled by the limiter.

When listening to music or speech with a fairly wide dynamic range, especially if there is any interfering external noise, if the maximum level is 85dB(A) the quiet passages will often be too quiet to hear well. So, if it can be done safely and legally, it is preferable to set the limiting level higher than this.

A limiting level frequently used is 93dB(A). This figure is based on analysis of a range of BBC broadcasts, recorded speech and music. Headphone limiter sets with a limiting level of 93dB(A) are almost certain to give actual noise exposures below the first action level of 85dB, when listening to most programme material.

However, listening to continuous heavily compressed rock music for eight hours per day could still give an exposure above the first action level, (although it would still be very unlikely to be above the second action level of 90dB). Conversely if the dynamic range of the programme is very wide, it might be necessary to use a higher limiting level so that the quiet parts can be heard properly, and in some circumstances, this could safely be done.

### What about insert earphones?

Earphones that are inserted into the ear canal such as are used by on-screen presenters, are often very sensitive and can produce very high sound levels at the eardrum from a modest drive voltage. So, when using them, safety should always be carefully considered. They also present some special practical problems.

One problem is that the drive voltage for these earphones may be too low to make the limiter operate properly. The high sensitivity limiter type EP5/29C was developed especially for this purpose, but even so, when used with very low impedance drivers it is often necessary to reduce the sensitivity of the earphone using the resistor chain built into the limiter for that purpose. If there is a choice it is often better to use a higher impedance driver that requires a higher signal voltage.

Such earphones are often used with "acoustic tubes", narrow-bore transparent plastic tubes that connect the driver to the earpiece. These tubes have a drastic effect on the sensitivity and frequency response of the earphone. The effect depends on their length of the tube, for example, a 50cm tube can introduce attenuation of about 20dB. So, if different lengths of tube might be used, a limiter must be set for the highest sensitivity situation, a short tube or no tube. There will be major changes in both sensitivity and limiting level when the tube is changed for one of a very different length.

The frequency response of systems with a fairly long tube is so uneven that the effective limiting level depends very much on the frequency content of the signal. The highest sound level will be obtained with a band-limited signal, so such a test signal should be used to set up the limiter. Playing wide-band music, or pre-equalising the signal to try to overcome the high frequency loss of the tube will still be safe, but the high-frequency content will cause the limiter to operate without producing a high sound level, therefore the effective limiting level will be reduced.

Because of these factors, simply substituting limited in-ear earphones for standard ones might cause a major reduction in sound level, that would be very disconcerting for the user. At the least a change in drive voltage will probably be required. The use of acoustic tubes, especially interchangeable ones of different lengths, should also be reviewed and it may be better to standardise on one length.



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### Customers' responsibility

Earphone limiters are an aid to achieving safety and to meet the requirements of health and safety legislation. However, individual customers' conditions of use are outside our knowledge and control. Therefore, Canford Audio cannot guarantee that legal requirements will be met merely by using earphone limiter systems supplied by us.

**Tony Woolf MSc, MIOA**

### Notes

- 1 A sound pressure of 200 Pascals, equivalent to the peak level of a pure tone whose RMS level is 137dB.
- 2 Suitable couplers conform to IEC 711 and ANSI S3.25 1979.

This technical briefing was written specially for Canford Audio plc by acoustics consultant Tony Woolf, who specialises in the design of broadcast studios, recording studios, as well as hearing protection for musicians and the professional audio industry. Between 1985 and 1996 he was an Acoustics Engineer in BBC Radio and then in BBC Building Design Services.

He was closely involved in BBC Radio's work to meet the requirements to UK noise legislation and provided the technical back-up for their large-scale introduction of earphones with limiters.