

The highs and lows of measuring sound

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What is a measuring range?

The fact that human hearing can detect everything from the faintest whisper right up to a large jet-liner taking off, is remarkable, especially when you consider that it is still difficult to make a sound meter that does the same. Yes, I know sound meters must do it accurately and need to filter frequencies in various ways, but still, the current fundamental electronic circuitry cannot cope with the same range as the ear. You can buy single range sound meters, but still most of these use a special “trick”, by merging two sets of circuits together to create the effect of a single range. The technology is improving and faster processors will overcome this problem, but then this is the 21st century!

Dynamic range

We can identify this as the ratio between the highest and lowest sound pressure levels the sound meter can measure.

A typical microphone may have a 140dB dynamic range, which is a signal amplitude ratio of 10,000,000 but your sound meter must determine this massive ratio to deliver a result.

The large ratio in input signal needs to be injected into ultra-low noise amplifier circuits before being sampled by an analogue to digital converter (ADC). Briefly, inherent noise from the circuitry and microphone, coupled with the resolution, bandwidth and sampling rate of the ADC limit the signal to noise ratio and hence reduce the overall dynamic range. This is where new 24-bit ADC chips are producing ever-larger dynamic ranges to help us solve this problem.

Single range sound meters are still subject to the same conditions and use circuitry and software to identify the cross over point, with a possibility of minor misrepresentation. Other sound meters use selectable ranges by the user which only operate within the selected measuring range.

The International standard governing the specification and testing of sound level meters is called IEC 61672-1:2013 Electroacoustics—Sound level meters (They also can have BS EN instead of IEC at the front). The dynamic range of a sound meter is officially called the Total Range and is everything the instrument can measure from the smallest sounds to the highest levels, without error!

Linear operating range v display range

You will usually see on your sound meter a number denoting the bottom and the top of displayed range, which is often set to a round-number to help with creating a scale that can be graphed conveniently. This is called the display range and isn't necessarily the same as the measuring range of the meter. The important factor is the ability for the instrument to measure in a “linear” way. This means that putting in a signal and changing it must result in a comparative change in the reading. Effects at the upper and lowermost extents of the range will change the output level until it is non-linear, where the errors will be larger than allowed by the standards. The correct term as used in the International Standard IEC 61672-1:2013 is linear operating range.

Noise floor v under range point

The noise floor of a sound meter is determined by two things. Firstly, and the largest factor is the “self-generated noise”, which is simply the electrical signals travelling around the circuits inside the sound meter creating a signal of their own. You can hear this as “hiss” on an old FM radio when you tune off-station and turn up the volume. The trouble with a sound meter is that they will measure this as a level that cannot be distinguished

from the sound at the microphone. If you imagine an electrical noise floor of 20dB and say that you are trying to measure environmental sound of 20dB, then what you see on the sound meter would be 23dB (double the sound energy); a significant error. Now imagine a noise floor of 15dB. There will still be an effect on the 20dB you are trying to measure, but will it cause the result to be unusable? In fact, a sound meter should allow at least 10dB above the electrical noise floor before the start of the lower linear measuring limit of the instrument, below which, an “under-range” message should be shown. This is why it looks like you can still measure below the under-range point on a sound meter - just be warned that these numbers will not be in specification! Some instruments show dashes instead of numbers below the under-range point, but most still give you a number!

The second factor in determining the under-range point is the microphone, as this also creates electrical noise, which adds to the self-generated noise level of the instrument. The combination of these two factors give the overall noise floor of the system, to which the (at least) 10dB “buffer” is added. There is a slight complication to this effect, which is the sensitivity variation of the microphone. Modern electret microphones are very good compared with the past, but they still vary from one to the next with a nominal 50mV/Pa (50 millivolts per Pascal) microphone often ranging from around 35mV/Pa up to 70mV/Pa. This will effectively move the noise floor of the instrument by up to plus or minus 3dB. Some sound meters account for this in the lower limit by adding more than 10dB to the electrical noise, whilst others will show a different under-range limit depending on the individual microphone capsule in use.

There is another “trick” that manufacturers can use, and that is by measuring the noise floor of the microphone, it is possible to “correct” or “linearise” the bottom of the dynamic range to take account of this. Meters which have a linearity range down to 20dB can still use a microphone with a noise floor of 15dB for example. The electrical noise will be more like 10-11dB, so the microphone is the limiting factor. However, this should only be done for a specific microphone, rather than microphone type.

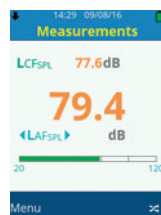
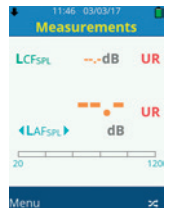
Audio recording at low noise levels

Many sound meters now have audio recording on them as standard. Fantastic, you might say! But beware, there are a few things to consider before lauding the technology too early. They all work well if you are recording high noise levels in a factory or for an industrial process based around the Regulatory action levels of 80-85dBA, or if you are just using it to annotate your measurements with voice-memo files. It is when you try to record low levels such as those found in rural outdoor settings, where you might find levels of 30-40dBA or even lower, you can encounter a few problems - especially if you are trying to listen to the audio afterwards for qualitative assessment!

To faithfully re-create sound that is audible and intelligible to humans means there must be enough detail stored in a file for a computer to re-play the sound through a speaker - that can be a lot of data!

Sampling rate and bits - what's it all mean?

Getting back to that sound means making a smooth wave out of single points of information. To do that, you need to break the wave down over the level and time. The smoothness of the change in level is determined by the number of bits used to describe it - the bit-depth. An 8-bit number is literally a series of 8 ones and zeros - 10111001, for example, which is 185 in “normal” numbers. The maximum number you can make is



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11111111, which is 255, so an 8-bit number can only represent 0 to 255 points on a scale, not very much if you are breaking down a measuring range of 20-120. You don't get a very smooth wave!

This effect gets worse at low levels because the scale for decibels is logarithmic where the steps between data points become bigger. Modern sound meters require at least 16bits audio recording to get anywhere near those low levels recorded properly. Many will now give you 24bit recording although some .wav file players will struggle to play these files.

The sampling rate is the smoothness over time, so a 44kHz sample rate will collect 44,000 points of information every second, and will give you a bandwidth of around 20 kHz. Lower rates will have lower bandwidths and may not be suitable for the task in hand. See figure 1.

Overload v peak

At the other end of the scale, you need to worry about overloading the electronics where the signal goes from the microphone pre-amplifier into the sound meter itself. Signals that are too large, get chopped off at the tops of the waves, which is called "clipping" and a sound meter must display an "overload" status to indicate that this occurred. Within the standards, it is possible to measure "peak" to a higher level than sound pressure and this is because sound pressure (rms.) is calculated from the overall waveform and will always be lower than the largest wave peak - see diagram below. Most sound meters using a 1/2" microphone capsule tend to measure up to 140dB sound pressure and 143dB Peak. Commercially, it is only the Control of Noise at Work Regulations that bring such high levels to bear, with the exposure limit value set at 140dBC Peak, which should be 3dB below the capabilities of most decent sound meters.

The requirement to measure higher than this, only really exists in some firearms testing and for those people who like to fill the back of their "blinged-up" cars with amps and speakers to create insane pressure waves of up to 160dB although, of course, this is not really sound but air-over-pressure and requires specially constructed microphones and pre-amplifier attenuators to be able to measure it.

Audio recording at high levels will give you plenty of information and a good audible output even at low bit-depths and sampling-rates, but there is an upper limit to this too, which is also determined by the range of the sound meter, so if the numbers are overloading, then the audio file will become distorted and less discernible. See figure 2.

How low do you need to measure anyway?

The measurement of low noise levels is certainly important in the assessment of environmental impact and for planning, but how low is low? A 'quiet' bedroom at night can be as low as 30dB (A)? (depending on the activities of the inhabitants!) and you will

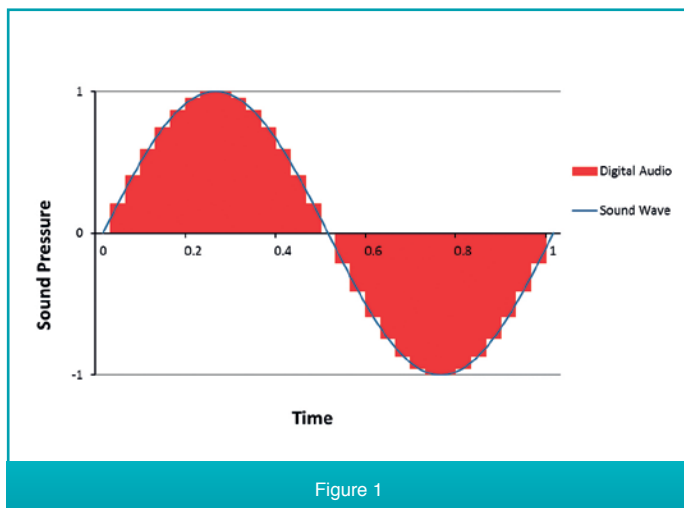


Figure 1

struggle to measure down to 25dB (A)? pretty much anywhere in the UK, unless you are in a specialist sound testing laboratory.

Quite surprising, then that manufacturers of sound meter are often asked for sound meters that measure down to 'at least' 20dB. Realistically, this is only possible with very specialised equipment and is not generally available in a standard sound level meter. Hmm.

As an extreme example of genuinely low noise levels, there was a gentleman, who once reported proudly that he was measuring in the peat bogs in Eire, and it was extremely quiet at night, as he got an answer of 18dBA everywhere he went! Didn't occur to him that that was the lowest his meter could read, so he wasn't measuring the actual sound at all! Most places aren't that quiet by a long shot!

Use your ears!

We increasingly tend to rely on technology in everyday life to solve our problems and we worryingly rely on the outputs, often to the exclusion of sense and reason - I expect most people have fallen foul of Sat-Nav routing anomalies leading you down a farm track you would normally avoid! Equally, relying on the numbers from a sound meter can lead to misinterpretation and false conclusions. One job we were involved in during March showed boundary exceedances every morning between 5am and 7am. It only took a human ear one minute to realise they were hearing a delightful, yet deafening, dawn chorus.

Conclusion

Understanding how the dynamic range of an instrument works can help prevent measurements on site being under or over range in the first place and whilst it is unlikely that measurements will overspill a dynamic range, where this is possible, careful selection of instrumentation will ensure good data. This is particularly important for meters with manual settings or multiple ranges.

You are likely to come across several phrases when dealing with this issue including "total range", "dynamic range", "linear operating range" (sometimes called linearity range), "measuring range" and "display range". It is important to note that "total range" and "linear operating range" are the only ones of any value, as they are the official terms used in the International Standard IEC 61672-1:2013 and are the basis for sound meter testing and verification.

Recording sound in the environment is increasingly popular as a means of providing a robust qualification of the acoustic events giving rise to measured sound. Where long duration sound recordings are required, particularly at high quality, this can be extremely memory intensive, and again should inform the choice of instrumentation used.

And finally, never forget that measurements and recordings, however robust, do not replace the need to perceive the sound directly using the human ear. ◻

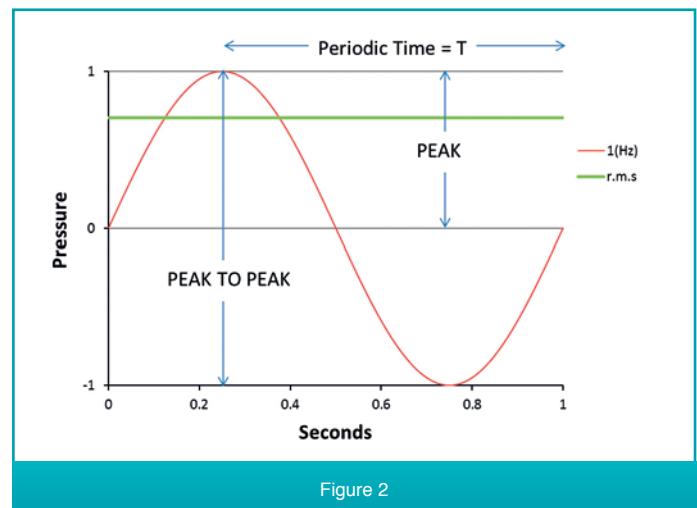


Figure 2