Recent and not so recent developments in sound measurement instrumentation

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Introduction

The 40th anniversary of the IOA is as good a time as any to review what has happened in the instrumentation market over the same period, and in particular, to the humble sound level meter.

This article reviews the basic architecture, and looks at how things have changed, often on the back of consumer electronics, and gives some pointers of where we are headed in the future.

The sound level meter

The basic layout of the sound level meter has not really changed over the years – we're simply trying to make an objective and traceable measurement of the noise level, to allow us to assess environmental noise impact or potential damage to workers' hearing, for example.

The building blocks of our meter are shown in Figure 1.

The starting point is of course the microphone, which transduces the acoustic pressure variation into a voltage analogue, which we can feed into our electronic circuits. Typically, we use a condenser type microphone, for its stability, linearity and ease of calibration. We need to polarise the capacitor, typically with 200 volts DC, and match its inconveniently high output impedance into something we can drive down the line. This requires specialised circuitry, taking the form of a dedicated conditioning preamplifier which normally sits just behind the microphone – the familiar silver tube.

Now we have a signal to work with, and two types of 'detector' are commonly used to make a measurement of sound pressure level. P16

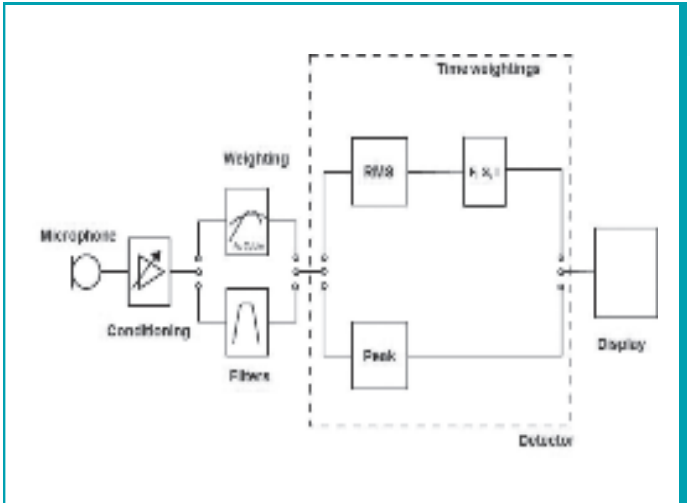

Figure 1

P15 The root mean square or RMS detector does what it says on the tin – backwards! Firstly, the waveform is squared, making all the negative excursions positive, then this is averaged to estimate the power in the signal, and finally the square root is taken to get back to a number which is related to a pressure *level*. The output of an RMS detector will fluctuate as much as the input signal, so in order for us to conveniently read the level on a meter, we need to 'damp down' these fluctuations, so a time constant is applied, the choice of which will depend on how much variation there is. We are of course familiar with the old standardised time weightings Fast, Slow and Impulse (more recently updated to just 'F' and 'S').

The Peak detector simply measures the maximum excursion of the acoustic signal (either positive or negative) and this might be useful for estimating damage potential from the noise, such as from blasting or gun shots. The peak detector will normally be used with a hold circuit to make the level readable.

The output of our detectors will be fed to a display, and traditionally, this was a high quality moving coil dial, which even did the decibel conversion to give a readout directly.

If we wanted to assess the noise level and not just the sound level, then there would also be frequency weighting circuits prior to the detector, A and C being the most popular, and for analysis of the frequency makeup of the signal, there may also be some filters, 1/1 octave or 1/3 octave being the most common.

Finally, statistical analysis of the fluctuations of the noise was starting to become interesting, for assessment of notional background noise level for example, and this was achieved, typically in the laboratory, by a fantastic array of equipment attached to the output of the sound level meter. Again, all realised in the analogue world (see Figure 2)

Forty years ago, all this was achieved with high quality analog circuitry from microphone right through to the display. The classic example of this was the B & K Type 2203, which was the weapon of choice for the serious noise warrior. Built in a hernia-inducing case, with all of the elements of our circuit realised with analogue switching, it remains today a great educational tool to understand the science of sound measurement.

The march of digitisation

No-one today could have overlooked the fact that everything is going or has gone 'digital'. The sound level meter was no different, and the process started at the back end of the chain – the display. By sampling the output of the detector, albeit at the slow sample rates (~1Hz) available at that time, the values could be displayed with greater precision on a digital display, to the nearest 0.1dB, and the limited dynamic range of the A/D converters could be improved by doing the log conversion in the detector before sampling.

Of course, the accuracy of the meter did not improve, but 0.1dB resolution was a lot more impressive! Some meters even combined analog and digital displays, such as the rare B&K 2210 (Figure 3).

The next step was to sample the detector output at a higher rate, which allowed some basic mathematics to be done, for example calculating the average value of the signal over a time period. At this time, the idea of the equivalent continuous sound pressure level, or Leq, gained a foothold, and this was easily estimated by sampling the output of a Fast time-weighted detector. The first 'integrating sound level meters' had been born.

Similarly, the samples could also be used for the statistical analysis, resulting in the breakthrough CEL-393 statistical integrating sound level meter (Figure 4), which swept the board in environmental health markets, despite having the user interface from hell!

However, sampling the output of a time weighted detector was always an estimate of the Leq, and as faster A/D converters with adequate dynamic range became available, the Leq could be calculated from the output of the mean-square detector directly – as we should all now know, 'F' time weighting has nothing to do with Leq.

The new family of digital sound level meters now followed the layout of Figure 5, with the output of the detector being sampled at 256 Hz for example. Note that the statistics were still sampled at a lower rate from the time weighted output, and currently there is still no standardisation of the calculation of statistical indices.

Also at this time, the concept of Short Leq emerged, where the digital detector spat out Leq values over short periods, commonly 125ms or shorter. This was ideal for the new idea of datalogging, where complete measurements could be sampled and stored to memory, for later display and processing on new-fangled computers. In fact, memory in sound level meters is a surprisingly new phenomenon – even in the early nineties, portable devices like Psion Organisers and Epson computers were being used to store sound level meter data!

In general, the weighting networks and filters were still realised as analogue networks – a frequency analysis required stepping through the filters one at a time, and hoping the signal was the same at the end, or even still there!

The trend in SLM development by now had been a slow increase in sampling rate, and dynamic range, and already, digital consumer audio was upon us – the compact disc emerging as early as 1982, with 16bit A/D converters and 44.1kHz sampling rates. The advent of low power digital signal processing suddenly made it realistic to digitise the output of the microphone preamplifier directly, and do the rest in Big Sums. Not an easy task necessarily, as our sound level meter still has to cover the complete range of human perception both in level and frequency, but now we can calculate weighting filters, 1/1 & 1/3 octaves, Leq and statistics completely digitally. The idea of digital dynamic range was no different to the old ways.

This simplifies our sound level meter down to Figure 6. Coupled with vastly increased memory, A/D converter and a DSP, almost anything is possible.

You could be forgiven for thinking that this makes sound level meters really easy to make, and therefore the price should drop dramatically. This is not wholly untrue, but there is still a huge skill in signal processing development, especially for our applications, and engineers who used to dabble in LCR circuit design have largely been replaced by firmware engineers, who still cost money for what is a small market compared to CD players. But price-wise, in the early 80s, an integrating type 1 sound level meter, with no memory, cost around £1,800. Today, a completely digital Class 1 sound level meter (Figure 7) with gigabytes of memory will cost around £1,200. A saving, yes, but not dramatic even allowing for inflation.

Completely digital?

Part of the reason sound level meters are relatively expensive, apart from the size of the market and development costs, is the microphone – the last analog bastion in the measurement chain.

Since precision sound level measurements began, the condenser microphone (Figure 8) has been the gold standard, the ½" capsule providing the best compromise in dynamic range and frequency range. Manufactured by a select few companies, the price of such capsules can be anywhere from £400 to over £1,000, a large chunk of the sound level meter budget.

However, for other much larger markets, such as hearing aids, telephones etc, a digital revolution has been happening in microphone development. The use of MEMS (micro electro mechanical systems) or micro-machined silicon transducers is now well established – the mobile phone in your pocket probably has not one, but several MEMS microphones built-in. These are used also for advanced noise cancellation, to make your phone call that much clearer both ends. P18

Figure 2

Figure 3

Figure 4

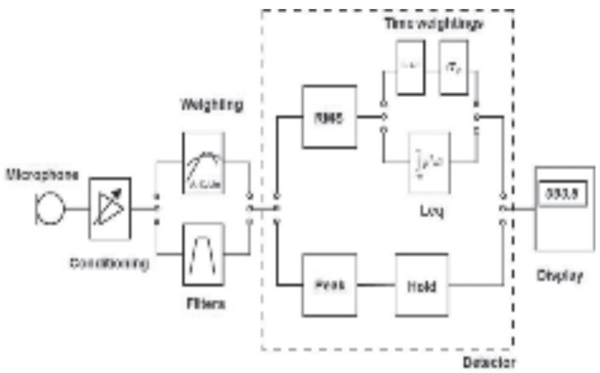

Figure 5

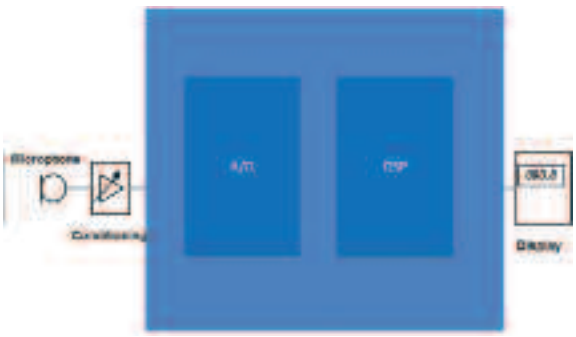

Figure 6

◀P16 MEMS microphones (Figure 9) are still based on the capacitor principle, but the capacitor is machined on to a tiny silicon wafer, which is packaged into a more manageable pot which can be directly soldered onto the circuit board. In some recent cases, the A/D converter can even be built in to the silicon, making what is effectively a digital microphone. MEMS microphones are also incredibly rugged, and of course, the low price of a few dollars is a real advantage.

Can these be used for *measuring* sound? The answer to that lies in the international standards that govern sound level meter performance, and right now, MEMS microphone performance falls short of those requirements. But already, there is a place for them – noise dosemeters (Figure 10) now employ MEMS techniques, as well as specialised techniques such as MIRE for in-ear measurements.

A recent project at NPL proved that a MEMS microphone meeting Class 1 tolerances is possible, so it is only a matter of time for many applications. This will undoubtedly reduce the size and price of sound level meters still further.

Consumer sound level meters?

Another trend in the market, now that everything can be done with an A/D converter and a DSP, is the rise of the App. Using the life support system of the smartphone (which already has MEMS microphones and DSP to burn), software applications are appearing which turn your phone into a sound level meter (Figure 11). Specialised extension microphones are also available to improve the acoustics and performance. Some even claim to meet sound level meter standards. Ironically, a few of these even have 'retro' analogue displays – a real full-circle!

As with PC-based sound level meters 20 years ago, we should still be sure that standards are met, and demonstrably so, so where do these apps fit in? The spectrum analyser apps for example are very good at finding the frequency of an audible tone, but when it comes to measuring the level, this is often only achieved accurately over a limited dynamic range. Also bear in mind that the electromagnetic environment inside a mobile phone is particularly hostile to low level noise measurements.

It's unlikely that Apple, Google, RIM and the like will ever go into the sound level meter market – it's just too small and specialised. Also, producing a new model or operating system every year will obsolete our phone-based instrument too quickly, but the traditional manufacturers can feed off the crumbs left behind – a Class 1 sound level meter with a MEMS microphone is not far off.

Summary

This article has, I hope, given an overview of sound level meter development over the last few decades, highlighting the move from analogue to digital, and consequent increase in value for money. Of course, the same progress applies to vibration meters, spectrum analysers and all manner of sound and vibration instrumentation – 20 years ago, a PC-based spectrum analyser was rocket science – now it's commonplace.

Where will it end? In my view, sound measurements will become even more integrated to the internet – maybe one day our digital MEMS microphone will connect directly to the Cloud, and our noise report will be written before we even get back to the office, along with weather, photos, GPS, maps. Plug your microphone into your Google glasses?

One thing's for sure, the Measurement & Instrumentation Group at the IOA will keep abreast of developments, and make sure the membership is kept informed about best practice!

***John Shelton** has been in the sound & vibration instrumentation business for over 30 years, and this year celebrates 20 years of AcSoft Ltd, pioneers of PC-based instrumentation. A member of the IOA, he is a founder member of the M&I Group and sits on several committees relating to sound & vibration measurement.*

Figure 7

Figure 8

Figure 9

Figure 10

Figure 11