STANDARDS – CONSTRAINING INSTRUMENTATION INNOVATION?

Roger Hawkins

Palmer Acoustics (Australia) Pty Ltd. Park Ridge, QLD, Australia
Email: roger@palmeracoustics.com

Abstract

Is our instrumentation moving with the times? Our current instrumentation owes it genesis to the condenser microphone, simple valve amplifiers and moving coil displays. The existence of highly integrated alternative devices for sound measurement, Micro-Electro-Mechanical-Systems microphones, are now familiar to all users of modern smart phones but not (yet) widely to acousticians. The standard for instrumentation, currently IEC 61672-1:2002 describes instruments with an analogue front end and a “don’t care” processing engine and sets, as it must, accuracy and stability requirements. The analogue part effectively precludes a fully digital system, from getting certification. Are the standards, formed last century, holding back some potential advances to the betterment of measurement and data processing? This paper, using a currently available MEMS data logging sound level meter as an example, looks at the advantages of a fully digital device and poses the question “Why Not?”

1. Introduction

This presentation is not intended to be an in-depth review but rather an overview and commentary on the constraints of history and practice on the acoustic instruments that we use every day. (Perhaps this is just as well as the research for this paper has showed up some of my own misunderstandings of our instrumentation history).

As no doubt all of you have noticed, there is no shortage of Android and iOS based phone apps that perform very well as Sound Level Meters (SLM) in terms of giving us numbers that look right and come with RMS and statistical metrics that are almost certainly calculated correctly. They are relatively robust compared to typical SLMs, particularly concerning their microphone component. They are fully digital, enjoying the advantages of significant data storage and low power consumption. And they do it at a lower price. But they are not replacements for typical acoustical instruments they are, after all, phones.

As has been frequently demonstrated and discussed in many papers at conferences such as this, typically the phone/SLM falls down concerning the microphone, its appropriate placement and the frequency shaping that is needed for phone use. Even when the response shaping is defeated the microphone placement is still less than optimal. Yet the smartphone/smart app combination does suggest that there may be alternatives to the traditional SLM. However at present standard for SLMs does not consider fully digital instrumentation. The suggestion of an alternative to the traditional SLM and the interaction of the concept with the defining standard is the genesis of this paper.

2. A Brief History of the SLM

In an article in 1957 Scott [1] described an acoustic survey of New York undertaken in 1929 using not Sound Level Meters (SLM) as we know them but an ear balance method where sound levels were judged against a reference level. Mr Scott further reports that the SLM was introduced about 25 years before his article, i.e. 1932. He identified then that the microphone was the weakest link in the chain of components compromising a SLM all of which required attention to stability, calibration and maintenance. (In 1932 an instrument of 21 kg was advanced and lightweight)

In the early 1930s SLM devices were priced at or above the cost of common cars, about $1000. While not a technical feature, the cost of early instrumentation has, I feel, a bearing on the direction of current development. SLM development has relied more on improvements in microphones than on the back end components of amplifier and display as these items were in constant development for use in other areas.

Early microphones, bypassing consideration of the carbon granule telephony capsules, were capacitive. In this form a charged sheet was placed near to an electrode and incident sound allowed to vibrate the sheet varying the capacitance formed by the sheet and the electrode. This movement varied the voltage stored in the capacitor and this voltage could read and the variations processed. To amplify the voltage variations high impedance amplifiers were needed and these were provided by the valve amplifiers in use at that time. A happy mix but one that required close attention to protection of signal paths from electrical noise. Leaving aside much of the technology of the microphone we can note that larger sheets/membranes would yield more sensitive microphones with consequently greater outputs which would have assisted with the signal processing and signal to noise ratios. Hence 1 inch preferred over ½ inch microphones for instruments of higher quality.

The move to semiconductor technology was initially a poor mix with instrumentation microphones until high impedance FET devices became available allowing the advantages of lightweight and low power to come to SLMs The need to protect signal paths also saw the integration of the initial amplifier (FET) into the microphone capsule and the separation of the pre-amp from the (electrically noisy) signal processing and digital circuitry.

Digital displaying of amplified and conditioned signals was an obvious step and one that didn't seem to alter the basic building blocks of the SLM. Add digital filtering and then memory and we have the form of our current SLMs. With the microphone still as the most fragile and weakest link and pertinent to the rest of this discussion it is an analogue sub system.

Robjohns [2] gives an informative look at microphone development and, writing in 2001, give an idea of where he felt microphones were developing. Another idea is the laser-velocity transducer where a vibrating reflective surface is scanned by a low power laser, the resulting Doppler shift conveying the audio signal. He also noted, however, miniature optical interfaces and related devices developed for the telecommunications industries, such as miniature laser diodes, polarising beam splitters and photodiodes, are now enabling the construction of high quality optical microphones. His concepts still seem to reflect the microphone as a separate analogue sub system in an SLM.

Figure 1. Battery powered and portable

3. Change Creeps in

To widen the discussion we note that Society meetings have played host to enthusiastic presenters, typically students, talking about the wonders of the smart phone/tablet as a measurement device. As a part of this concept we see the microphone as an integrated part of a system, where often an analogue microphone signal is not available or needed. Typically these microphones are Micro-Electro-Mechanical-Systems microphones or MEMS devices. An overview of this technology is available from Lewis [3] however it is possible to describe the microphone sensing element as a capacitor and therefore the device as a capacitive microphone. Where it differs, however, is in the size of the element which is integrated onto the silicon of the signal processing circuitry. The devices are presented in several forms, specifically consisting of a sensing element and an analogue or digital Application-Specific Integrated Circuit (ASIC), encompassing analogue and digital outputs. There are advantages in the digital output form where signal processing is to be carried out in an electrically noisy environment, e.g. a smart phone, where the analogue signal is not required e.g. digital sound recorder and where low power is an advantage.

In their paper looking at the use of smart phone based systems Robinson & Tingay [4] compared these systems to traditional SLMs. They suggested that a smart phone system where hardware and software were specifically co-ordinated in the hands of a qualified professional would be a useful tool when used appropriately, cognisant of the limitations of the system. However the article detailed the significant limitations of the process and the difficulty in using a general purpose device, a smart phone, in a specific application where other functions are included in the system, i.e. it's still a phone and subject to software updates of unknown effect on the SLM function. While they mentioned IEC-61672 [5] I wish to have a slightly deeper look at this in relation to newer technologies.

4. The Standard

IEC 61672, Electroacoustics — Sound level meters, to give it its full title is a standard that describes (Specifies) classes of SLMs and how these are to be tested/certified. The need for a standard to regulate SLM performance is hardly to be questioned, we all need to know that a reading is the same from SLM to SLM.

Part 1 of the document, Specifications, fully details what a conforming SLM is to measure, what the terms mean and accuracy parameters. It also contains statements not directly related to the performance of the meter:

Part 5 – *Performance specifications*

5.1 General:

5.1.1 Generally, a sound level meter is a combination of a microphone, a preamplifier, a signal processor, and a display device. Performance specifications of this standard apply to any design for microphone and preamplifier that is appropriate for a sound level meter.

and

5.1.16 the microphone shall be removable to allow insertion of electrical test signals to the input of the preamplifier.

It further references IEC 60050-801:1994 definition 801-26-01:

Microphone

Electroacoustic transducer by which electrical signals are obtained from acoustic oscillations.

By statements such as those above the standard regulates a form of SLM that may not be the only possible configuration in 2015. The statement that a microphone produces electrical signals precludes the optical microphones that Robjohns spoke about and excludes the class of MEMS where the microphone output is processed on chip to a digital only signal. The requirement for the microphone to be removable to allow insertion of electrical test signals, as a, perhaps unintended, consequence mitigates against fully integrated systems.

5. Overreach

I feel that the standard over-reaches the necessary description of what is to be measured, the terminology of measurement and accuracy classes to mandate convenience measures that allow for simpler testing and on-going certification procedures. This attitude is also evident in the descriptions of what information is required to be in the instrumentation manual and the list is extensive.

It is possible to conjecture that the description of a complying SLM was made so tight as to support manufacturers that were already in the market and the form of instrument that they produced and perhaps to act as a disincentive to new entrants. That the systems would have been expensive is not of itself an issue as all would have been required to produce meters of equal complexity and at professional costs.

If I finished the paper at this point it would be simply a complaint going no-where but I have a realisation of a MEMS solution that puts the previous statements into a context and looks at the advantages of a fully digital instrument.

6. Practical Instrumentation – A Mems Example

Shown in Figure 2 are two self-contained MEMS noise loggers with approximately 7 day battery life and 30 day data capacity depending on sampling rate. More specifically, when storing LAmax, LAmin and LAeq 8 times a second battery capacity is 30 days. Data is internally processed to give dB (A) or dB (C) results. One of the instruments is Wi-Fi capable. They are fully digital, i.e. there is no analogue interface which contributes to the low power demand. They have no display and do not have the ability to remove the microphone and pre-amp. The packaging includes a ½ inch microphone form that is compatible with standard calibrators. Communications with the instruments is either via Wi-Fi or USB Mini-b connector. The software supplied with the instrument covers all the bases providing instantaneous readings, control of data storage, control of measurement time constants and frequency from a FFT analysis. Octave band storage is not available in the current computing/battery performance trade-off. Typically data is gathered multiple times per second and post processed to yield statistical metrics and chosen time intervals, e.g. 15min LAeq. The instruments enjoy the common full digital advantages of low cost and light weight.

Regarding accuracy of weighting and linearity the manufacturer supplies certification that A and C weighting are within IEC 61672 limits. An extract of that certification, the Weighting Network Tests (IEC 651 #9.2.2 and ANSI SI.4 # 8.2.2) from Scantek Inc. [6] is presented as Tables 1 & 2 below. The certificate records “Passed” results for Level and Differential Linearity tests, Slow/Fast time constant tests and RMS Crest Factor Tests among others. The noise floor is around 30 – 33 dB(A).

Table 1: Weighting Network Test - A Weighting

Input Level 94.1 dB

	A Weighting network				Tolerance [dB]				
Frequency [Hz]	Measured pressure response [dB re 20µPa]	Free Field Response* [dB re 20µPa]	Reference Level [dB re 20µPa]	Result	Type 1		Type 2		Expanded uncertainty (con. Fact. 2) [dB]
31.5	55.1	55.1	54.7	Passed	1.5	-1.5	3.0	-3.0	0.2
63	67.7	67.7	67.9	Passed	1.0	-1.0	2.0	-2.0	0.2
125	77.9	77.9	78.0	Passed	1.0	-1.0	1.5	-1.5	0.2
250	85.2	85.2	85.5	Passed	1.0	-1.0	1.5	-1.5	0.2
500	90.7	90.7	90.9	Passed	1.0	-1.0	1.5	-1.5	0.2
1000	94.1	94.2	94.1	Passed	1.0	-1.0	1.5	-1.5	0.2
2000	95.1	95.4	95.3	Passed	1.0	-1.0	2.0	-2.0	0.2
4000	93.9	95.0	95.1	Passed	1.0	-1.0	3.0	-3.0	0.3
8000	88.7	92.1	93.0	Passed	1.5	-3.0	5.0	-5.0	0.9

*The pressure to free-field corrections were provided by the manufacturer

Table 2: Network Weighting Tests - C Weighting

	C Weighting network				Tolerance [dB]				
Frequency [Hz]	Measured pressure response [dB re 20µPa]	Free Field Response* [dB re 20µPa]	Reference Level [dB re 20µPa]	Result	Type 1		Type 2		Expanded uncertainty (con. Fact. 2) [dB]
31.5	90.7	90.7	91.1	Passed	1.5	-1.5	3.0	-3.0	0.2
63	92.8	92.8	93.6	Passed	1.0	-1.0	2.0	-2.0	0.2
125	93.7	93.7	93.9	Passed	1.0	-1.0	1.5	-1.5	0.2
250	93.9	93.9	94.1	Passed	1.0	-1.0	1.5	-1.5	0.2
500	94.2	94.2	94.1	Passed	1.0	-1.0	1.5	-1.5	0.2
1000	94.1	94.2	94.1	Passed	1.0	-1.0	1.5	-1.5	0.2
2000	93.4	93.7	93.9	Passed	1.0	-1.0	2.0	-2.0	0.2
4000	92.1	93.2	93.3	Passed	1.0	-1.0	3.0	-3.0	0.3
8000	87.1	90.5	91.1	Passed	1.5	-3.0	5.0	-5.0	0.9

*The pressure to free-field corrections were provided by the manufacturer

At Palmer Acoustics we have placed the instruments in the field alongside our class 2 loggers and noted equivalent results, to the point where we now present results exclusively from these instruments in noise assessments. In use the instruments are calibrated before and after placement and exhibit stability equal to our Class 2 instrumentation. By moving away from the certified Class 2 form we have been able to realise a number of advantages particularly from the perspective of field work.

From Figure 2 the small size of the device is apparent. In one of our first field applications 5 devices were placed in a shopping mall to investigate noise levels from a mid-mall child’s play area. Most devices were secured near the ceiling where they were completely unobtrusive/unnoticed. A further device was pole mounted to a book display case in a retail outlet where is remained undisturbed during the measurement period. We enjoyed the advantage of simultaneous measurement results and easy placement of the meters, outcomes that we couldn't have realised with or traditional meters.

Figure 3 shows a meter mounted on lengths of 1 inch water pipe, a typical mounting. Devices are mostly secured in the field with zip ties to fences or trees. Physical security is principally provided by being mounted out of view or out of reach (trees). Personally I greatly appreciate the ease of climbing ladders with a length of pipe and a 140 gram instrument over hauling up a traditional >12 kg logger/battery combination.

Figure 2. MEMS based loggers

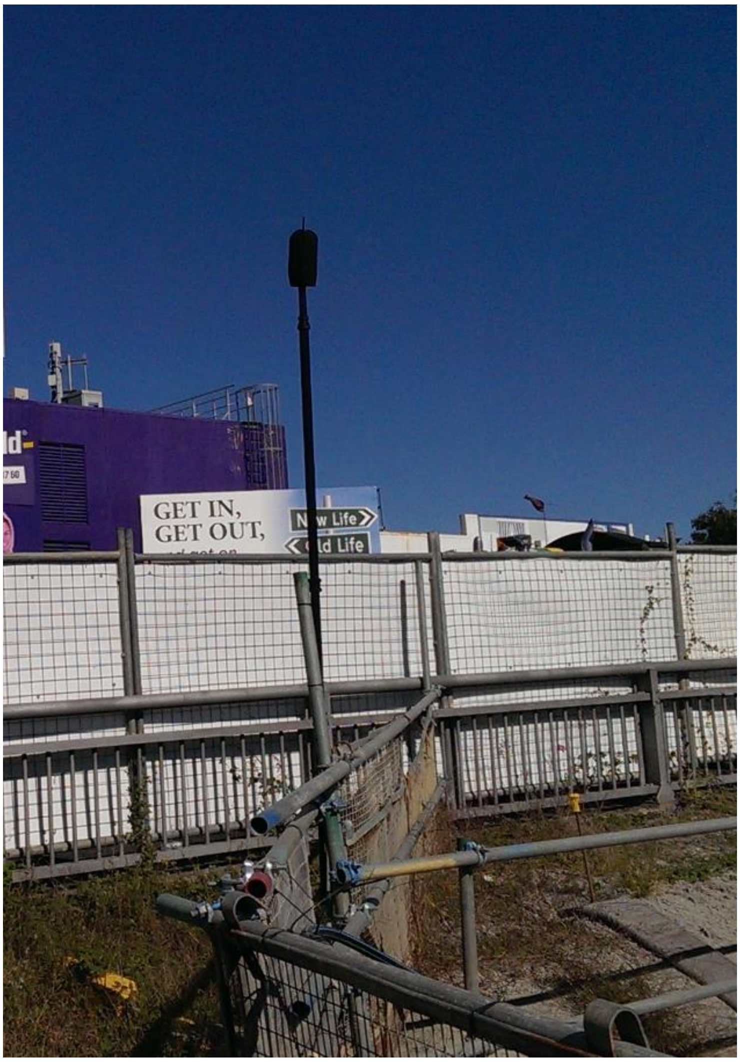

Figure 3. Field mounting

Without directly contradicting Robinson and Tingay [5] we have found that these instruments can be placed in the hands of the general public. For more remote (from the office) tasks we have previously found that it is convenient to place a logger and to have it returned by our client. The size and light weight of the MEMS device make this far easier and less hazardous to the instrument in the hands of a courier. We consider the water pipe mounting ($4 from Bunnings) to be expendable, i.e. not worth the expense of returning. For tasks where low budget is a significant consideration, i.e. an assessment for a Men's Shed on a Morton Bay Island, the instrument was setup in the office and posted to the client. It was returned along with photos of where it was installed allowing a significant saving to the client organisation.

Along with easy deployment having instruments easily time synchronised, to the programming PC, and recording at 1 second intervals give high confidence when monitoring inside/outside noise levels as in a recent traffic noise assessment.

In combination with a Wi-Fi hotspot device and solar cells a cluster of instrument is able to be simply deployed and longer term data gathering undertaken. While hardly a unique application, with all traditional suppliers offering remote logging stations, the low cost and small size of the MEMS devices make this a far more attractive option.

7. Conclusion

On review, I was asked if I was proposing MEMS based loggers as a replacement for class 2 loggers. As I have stated, I am using them in the field as direct replacements for class 2 loggers and I suggest that they are near-fully equivalent to Class 2 instruments.

Acknowledgements

I would like to acknowledge the input and support of (1) Robert Thorne PhD, Acoustar Pty Ltd, (2) Bruno Pallard PhD, Senior Designer Convergence Instruments, and (3) Ross Palmer, Principal Palmer Acoustics Pty Ltd.

References

[1] Scott, H. H. "Historical development of the sound level meter", *Journal of the Acoustical Society of America*, **29**(12), 1331-1333, (1957).

[2] Robjohns, H. "A brief history of microphones" *Microphone Data Ltd*, 2010.

[3] Lewis, J. *Analog and digital MEMS microphone design considerations*, Technical Article MS-2472, 2013. Available at: http://www.analog.com/media/en/technical-documentation/technical-articles/Analog-and-Digital-MEMS-Microphone-Design-Considerations-MS-2472.pdf.

[4] Robinson, D. P. and Tingay, J. "Comparative study of the performance of the smartphone based sound level meter apps", *Proceedings of the 43rd International Congress on Noise Control Engineering (Inter-Noise 2014)*, Melbourne, Australia, 16-19 November 2014.

[5] IEC 61672 Electroacoustics – Sound level meters, *International Electrotechnical Commission*, 2003.

[6] Scantek Inc., a wholly owned subsidiary of Norsonic AS. www.scantekinc.com