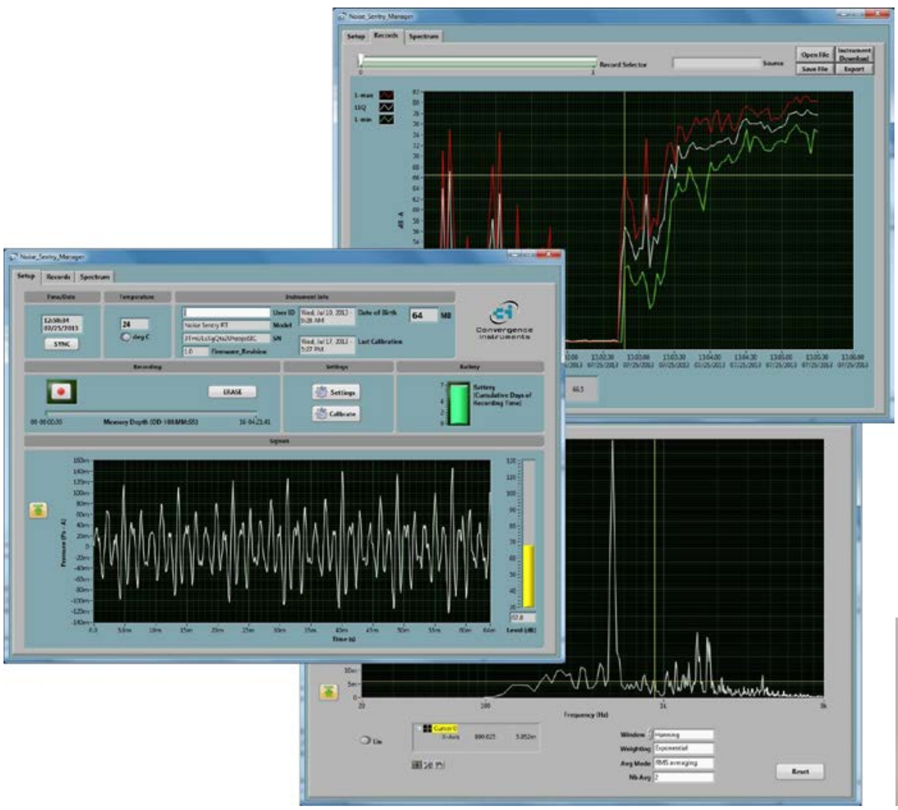
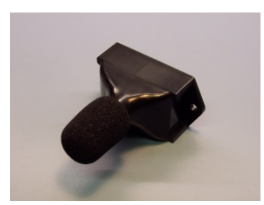
Convergence
Instruments

Environmental Noise Control

Trends in Instrumentation





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1 Noise Control

Throughout the world, there is renewed effort to control noise levels in residential areas. High noise levels interfere with sleep and various human activities. In the long run it does not just affect the quality of life, but also causes physical ailments such as heart disease [1], [2]. Many cities, regions and countries have established limits on the amount of noise that the population should be subjected to.

Integrating Sound Level Meter technologies and microphone technologies have evolved over the years, and have reached a point where precise reliable instruments have the required autonomy to record sound levels for long periods of time, and the required low-cost to be deployed in large numbers.

2 Noise Measurement Technologies

Noise control begins with a physical measurement of the noise levels in the area of interest. Traditionally noise measurements are carried out by a *Sound Level Meter* - or *"SLM"*.

Sound Level Meter technology has evolved quite a bit over the years. In the days before digital technology was common-place, sound level meters were based on analog circuitry. A microphone produces a signal that is rectified. The rectified signal is filtered with a first-order averaging filter, and the resulting "level" or "amplitude" is displayed by a galvanometer. Traditionally three time constants are used for the averaging filter:

- Extra-Fast (35ms). This is often used for peak detection.

- Fast (125 ms – or 1/8s). With the fast time constant the instrument is very responsive to fast changes in sound level.

- Slow (1s). With the slow time constant the instrument is very sluggish and will average-out fast changes, producing a reading that is much more constant in time and representative of the average sound level.

This analog technology is adequate to perform an instantaneous or short-term measurement, but because environmental noise often varies in time, measurements for environmental studies need to be carried out over long periods of time. An intermediate technology that helps in that regard is designed around a standard analog sound level meter, but with the addition of a sampler to digitize the measured levels and record them to memory. These recording sound level meters are basically analog instruments that have the capability to record levels digitally over time.

Most present-day sound level meters are based on a digital sampling of the acoustic signal itself, and digital computation. Such entirely digital processing results in perfect instrument linearity over the whole dynamic range of the microphone. Using that technology it is relatively straightforward to calculate the energy of the sound over fixed intervals of time. Such energy quanta are called LEQs (for Equivalent Levels), and represent the level of sound, averaged over fixed time intervals, rather than averaged using a first-order filter. This energy integration is the basic processing within instruments called *Integrating Sound Level Meters* and is the basis of *noise dosimetry*. *Integrating Sound Level Meters* are always all-digital systems, and given that digital technology, it is not difficult for them to record those LEQs to memory over time.

3 Microphone Technologies

Sound Level Meters are traditionally built around two families of microphones:

- **Electrostatic measurement-class microphones:** These microphones are well built, individually tested, with a well-controlled frequency response and sensitivity. However they have two major drawbacks:

    - They are expensive. The microphone itself can cost up to several hundreds of dollars. That does not include the preamplifier, which itself can be several hundreds of dollars.

    - They consume a relatively large power, which is not conducive to the long battery autonomy required for environmental studies.

- **Electret Microphones:** These microphones are intended for the consumer-electronics market. They are much less expensive (usually only a few dollars) and consume a very small current at low voltage. But they have a frequency response that is less well controlled.

In recent years a third family of microphones has appeared in the industry:

- **MEMS microphones:** *Micro-Electro-Mechanical Systems.* These microphones are built using the same silicon etching processes that are common-place in *Integrated-Circuit* manufacturing. This presents two advantages:

    - The manufacturing process is very well controlled, yielding microphones with very well controlled characteristics.

    - It is relatively straightforward, and inexpensive, to include complex electronic circuitry to the microphone itself.

Some of these MEMS microphones, such as InvenSense's *INMP441* used in the *Noise Sentry RT*, include circuitry to convert the acoustic signal to a digital stream directly at the component level. This presents several advantages, including simpler lower-cost system circuitry, better characteristics, such as noise and frequency response… etc.

MEMS microphones target the consumer-electronics market and are therefore low-cost. In recent years their quality has improved to the point where they rival entry-level measurement microphones. There is commercial pressure for even higher quality MEMS microphone, for mobile phone and tablet applications. Therefore it is only a question of time before we see MEMS microphone with characteristics equal or better than the best measurement microphones.

4 Environmental Noise Metrics

Since the emergence of psycho-acoustics in the 1950s and 1960s, scientists have proposed ways to quantify the amount of "annoyance" caused by noise to the people who are subjected to it. Through the years these noise metrics have evolved, and some have become standards. Nowadays many local and national regulations are based on such standards. These standards vary from region to region and country to country, but most are based on the amount of A-weighted energy carried by the noise over a specified duration of an hour, a day, a year…etc.

The basis for the calculation of most of these metrics is the short-term LEQ. The standard instrument to produce the raw data for these metrics is the *Integrating Sound Level Meter*. A small time-interval is not essential to the calculation of these noise metrics but it can help in the following ways:

- It allows better insight into the dynamic changes of the sound level over time. The shorter the interval the easier it is to detect short high-level transients.

- Some noise metrics are based on the detection of *events* and their associated sound energy (the *Sound Exposure Level* or *SEL*). Such events can be airplane fly-bys or train pass-bys. In order to properly detect such events, and measure their level and their duration, the LEQ levels must be recorded with a time resolution that is much smaller than the duration of the events themselves. A resolution of one second or lower is often an advantage.

In many instruments on the market these complex noise metrics are calculated directly at the level of the instrument. At *Convergence Instruments* we think that it is better to perform the calculations off-line. That allows the instrument to be much simpler, have a lower computational power and consequently a lower power consumption, to be able to measure for longer periods of time. This also lowers the cost of the instrument. Finally the fact that the noise metrics themselves are calculated on a personal computer provides much greater flexibility, richer displays and much more intuitive user-interfaces. New noise metrics or adaptations can easily be implemented by software upgrades.

5 Qualities of an Integrating Sound Level Meter for Environmental Studies

A lot of emphasis is often placed on the precision of the instrument. However, because of its special function, the qualities of a good *Integrating Sound Level Meter* for environmental studies go beyond precision.

- **Long Battery Time:** Environmental studies require data to be recorded over long periods of time. The instrument needs either a long battery time, or means to connect it to an external power source, or both. The *Noise Sentry RT* has a battery time of 1 week, and can be connected to an external USB charger or battery for much longer recording times.

- **Large Recording Memory:** The raw data for environmental studies are short-term LEQs. Reducing the LEQ's interval to short periods increases the time resolution and provides greater insight into the dynamic changes on the noise level. The *Noise Sentry RT* can record 1s LEQs for three months. It can record 1s LEQs, in addition to min and max levels for 1 month.

- **Weatherproofing:** An *Integrating Sound Level Meter* for environmental studies must often work outdoors. A weatherproof construction is a great advantage. The *Noise Sentry RT*'s is completely potted in epoxy. This protects it from the elements without impairing its acoustic response.

- **Low Temperature Dependence:** Because it must work outdoors an *Integrating Sound Level Meter* for environmental studies must have a microphone which sensitivity varies very little with temperature. Despite its low cost, the microphone used in the *Noise Sentry RT* is extremely stable in temperature. This makes it a very good choice for such applications.

- **Low Cost:** Low cost means that a large number of instruments can be used, covering a larger territory and yielding much richer data than what is possible with a single high-priced instrument. That large coverage means that the data is more reliable. A single instrument, no matter how precise it is, will never capture the "whole picture". There are many instances where data is biased at the chosen location. There is strength in numbers and that strength can only be achieved if the instruments are affordable enough to deploy them in larger numbers.

6 References

[1] *Burden of disease from environmental noise - Quantification of healthy life years lost in Europe* World Health Organization Regional Office for Europe 2011.

[2] *Noise Pollution: The Sound Behind Heart Effects World Health* – M Nathaniel Mead - Environ Health Perspect. Nov 2007; 115(11): A536–A537