Let's get down and dirty - Measurement of low sound levels

Improving noise awareness is resulting in the measurement of L_{90} or L_{99} figures that can be very low at times and this is focusing on the performance of sound level meters at the bottom of their dynamic range. So let's have a look at the parameters that control how well they work down there. The two controlling parameters are the microphone sensitivity and the level of self noise in the instrument; obviously the signal from the microphone must be high enough to swamp the self-noise of the instrument so that the measurement is based on the microphone signal and not the artefacts generated by the instrument. The two signals add energetically so as long as there is a large enough difference you can ignore the lower. The actual relationship is shown in figure 1 but as a rule of thumb for a 20dB difference the error is zero, 10dB gives +0.4dB and when the self noise and microphone signal is the same the resultant is 3dB higher. Some manufacturers employ this relationship to include a correction algorithm in the instrument firmware to correct for the self noise in the area between 3 to 20 dB above the self noise; but you can make the correction yourself by taking the self noise figure quoted on the sound level meters' calibration certificate using the following relationship:

$$L_R = 10Lg\left[10^{\left(\frac{L_T}{10}\right)} - 10^{\left(\frac{L_N}{10}\right)}\right]$$

Where L_R = Resultant true sound level in dB
L_T = Total measured sound level, i.e. sound plus the self noise in dB
L_N = Known self noise of the preamplifier in dB

But don't use this relationship if the difference between the measured level and the known self noise of the system is less than 3 dB; also take note of the comments later about the self noise of the microphone itself.

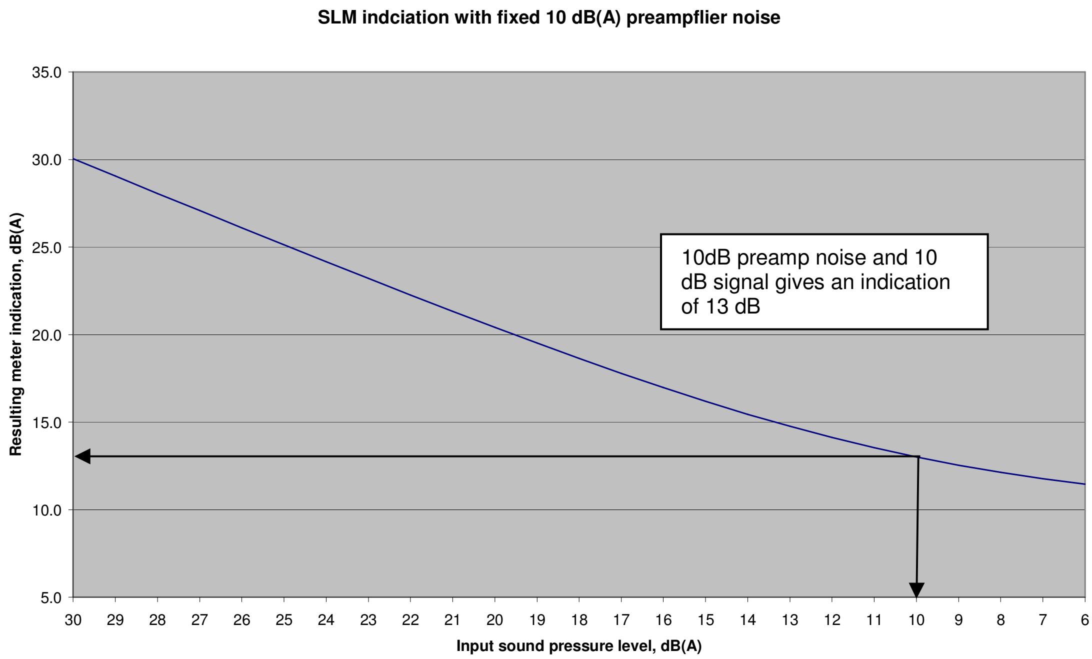

Figure 1 Effect on meter indication for a 10 dB self noise in the preamplifier

So when measuring low sound levels it is a good thing to have a microphone with a high sensitivity, most microphones are now ½ inch devices and have a sensitivity around 50 mV/Pa[1],. There are some older

[1] Basically they produce 50 mV for a 94 dB sound pressure level

½ inch devices about with a sensitivity of around 12 mV/Pa and these will naturally be some 12 dB worse when it comes to the measurement of low sound levels. Sensitivities quoted in the manufacturer's data sheets are nominal and actual production units can vary by ±3 dB on these; so there could be a difference of 6 dB between the performance of two microphones of the same type in respect of signal to noise ratio

There is another complication to bear in mind in the complex interaction between the preamplifier and the microphone. The capacitance of the microphone also plays a part; the higher the capacitance, the lower its impedance and hence a lower the self noise will be generated. So 1 inch microphones that also have a sensitivity of 50 mV/Pa will result in lower self noise than a ½ inch 50 mV capsule due to the fact that their capacitance is 55pF against 20pF. Electret microphones have an even lower capacitance than air condenser units so for a given sensitivity they will not be as good on self noise as their capacitance is down at 13pF. It is important to bear in mind that microphone designers are continually balancing the many parameters to optimise performance in various areas; but for low sound level measurements high sensitivity and capacitance are the parameters to go for.

Weighting	**Dummy microphone capacitance**		
	13pF ½" Electret condenser	**20pF ½" Air condenser**	**45pF 1" Air condenser**
dB(A)	9.5	7.7	5.3
dB(C)	13.2	11.9	7.4
dB(Z)	21.9	20	14.8

Figure 2 Typical variations in self noise with microphone capacitance
For ease of comparison all have been assumed to have 50mV/Pa sensitivity

Taking a standard 50 mV/Pa microphone and looking at the output at say 14 dB sound level we will be looking at voltage levels of 0.005 mV (5µV) so the voltage levels are very low and it is the job of the preamplifier to ensure that this is correctly coupled to the sound level meter with as small a loss as possible. A good quality preamplifier will do this with coupling losses of around 0.2dB but there are units around that have coupling losses of several dB. The use of a driven shield in the preamplifier, this is an additional screening electrode around the contact pin that is driven with a shielding signal, is one of the techniques to minimise coupling losses and examples of preamplifiers with and without this additional component are shown in figure 3. Naturally a driven shield is more expensive to manufacture but also bear in mind that preamplifiers may be made deliberately to have a loss to improve their performance at high sound pressure levels.

Figure 3 Preamplifier on the left has a guard ring and will have
approximately 3dB better signal to noise than the one on the right

Unfortunately, it is not only the preamplifier that contributes to the self noise level. The microphone itself plays a part. The thermal agitation of air molecules is sufficient for a microphone to generate a very small output signal, even in absolutely quiet conditions. This "thermal noise" lies normally at around 5 µV and will be superimposed on any acoustically-excited signal detected by the microphone. Because of this, no acoustically-excited signal below the level of the thermal noise can be measured. This 5 µV output signal is equivalent to a certain "apparent" sound pressure level which can be calculated from the sensitivity of the microphone. For a microphone with a sensitivity of 50 mV/Pa, this would correspond to an apparent sound pressure of:

$$\frac{5\ \mu V}{50\ mV/Pa} = 0.0001\ Pa\text{; in other words, around 14 dB spl}$$

Similarly, for a microphone with a sensitivity of 4 mV/Pa, this would correspond to an apparent sound pressure of:

$$\frac{5\ \mu V}{4\ mV/Pa} = 0.00125\ Pa\text{; in other words, around 36 dB spl}$$

Hence, a microphone with a sensitivity of 50 mV/Pa can measure down to a few dB above 14 dB whereas a microphone with a sensitivity of 4 mV/Pa can only measure down to about 36 dB.

So we have to consider how these two functions act together to give the lower limit to the measurement range of the instrument. To do this it is necessary to consider the typical spectra of the preamplifier self noise and that of the thermal noise of the microphone itself. These are shown in figure 4 and it can be seen that the preamplifier noise has its main energy at low frequencies whilst in the microphone it is at mid frequencies. So it is possible to quote very good dB(A) noise figure for the preamplifier, some standard units are as low as 6 dB(A), but the microphone noise for a 50mV microphone will control the result and give a limit of around 14 dB(A).

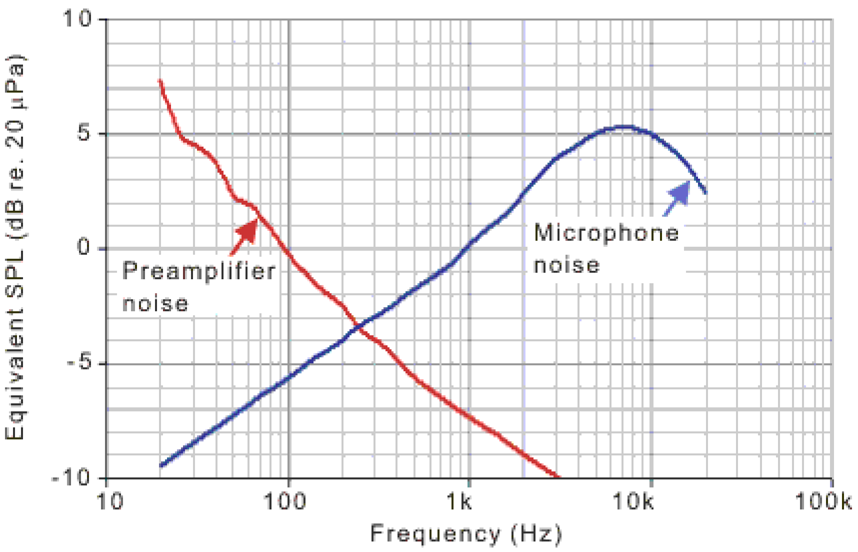

Figure 4 Noise spectra of the microphone and preamplifier self noise.

With this information it is possible to make reasonable estimates of the lower limit of noise that can be measured with any individual instrument. Don't forget that the inclusion of extension cables or other accessory units may increase the self-noise; for example, some specifications say in the small print that self noise is quoted for battery operation so higher figures may apply if the unit is powered from a mains unit etc. Also take care when routing extension cables to keep them away from electrical equipment as there is always a risk of electrical interference increasing the self noise. There are a couple of bits of test kit you can use to help in these cases. A dummy microphone is a device used to determine the self noise by screwing it on in place of the microphone; they come in different capacitances to model the microphone type fitted to your meter. Most also double as a line input adaptor so you can also use them to couple electrical signals to the instrument. If you have a dummy microphone in the sound level meter kit it is always good practice to check there are not any noise artefacts in the measurement chain before you start the measurement.

Secondly some models of weather protected measurement microphones have a noise suppressing cap that fits over the microphone and rain shield assembly and seals around its preamplifier to shield background noise; if you use one of these to check a system don't forget to cover the small atmospheric bleed hole that is there to allow air to escape as you screw it on as it can make a difference of a few dB. An acoustic calibrator over the microphone in a quiet room is another method that can be used to check if the microphone has gone noisy; look for levels on the meter that do not correlate with the acoustic climate as being an indication of self noise in the microphone.