Field Manual

Introduction to Sound Level Measurement Engineering

dB (A)

2nd revised edition

Index for Sound Level Measurement Engineering Handbook

1. The sound parameter

The human ear is the most used sense organ in the human body along with the eye. Due to sounds around us - conversation, music, birds singing or machine noise - the ear enables us to participate in our environment. The ear is a precious sense organ which should be protected. In our professional life, sounds such as machine noise are produced, which we consider disturbing. Everyone knows that noise and sounds, which are too loud, can damage the ear permanently. The new testo 815/816 sound level meters are modern sound meters which enable us to measure and analyse sound, noise or pure tones. But what is sound?

1.1 Sound waves as fluctuations in air pressure

We perceive sound due to the fact that the air pressure alters at the place in which the sound is produced. Each change in pressure is sound.

If it is perceivable for the human ear, we talk of **audible sound.** The most commonly-known instrument for measuring changes in air pressure is the barometer. The barometers, which measure changes in pressure following a change in weather, are too slow for fluctuations in pressure caused by sound waves. Pressure probes are not suitable for this task. A suitable pressure sensor with the corresponding sensitivity and measuring speed is the **microphone.** The pressure fluctuations which occur with audible sound are very, very small. At a normal pressure of 1013 mbar, changes in the bar range are sufficient to irritate the ear. The enormous sensitivity of the human ear and the dynamic range it covers will be dealt with later.

1.2 Frequency / Wavelength

The number of changes in pressure per second is called the **frequency** of sound. It is measured in **Hertz (Hz)**. The frequency of the sound is responsible for the **characteristic tone.** High tones have a high frequency, low tones have a low frequency. We are familiar with the swinging movement of a pendulum from mechanical engineering.

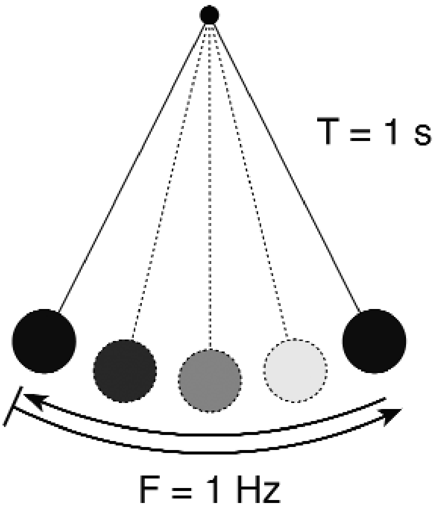

Figure 1: Mechanical oscillation

If the sphere is moved from the middle and let loose, it begins to swing. The period of time between letting go of the sphere and it reaching the same place again, is called a **cycle duration.** Should the above-described sphere require exactly one second to swing back and forth once, we refer to a cycle duration of one second. The frequency is only the reciprocal of the cycle duration.

This means:

$$F = \frac{1}{T}$$

Example: Our pendulum swings 7 times a second. The frequency of the pendulum is thus 7 Hz. The cycle duration is calculated as follows:
1 : 7 = 0.143 seconds. The pendulum thus requires 0.143 seconds.

Should sound waves be produced from a vibrating object, other than the above-mentioned sphere, e.g. from a loud-speaker, we can hear these oscillations as **sound**. The sound waves must be within a **frequency range** of 20 Hz to 20 000 Hz. The measuring range from 20 Hz to 20 000 Hz is also called the **audible range** of the human ear.

The sound parameter

We know from physics that noise expands at 344 m/s in the air. If we know the speed and frequency of the noise, we can calculate its **wavelength**. The wavelength is the distance from one pressure peak to the next. The equation for the calculation of the wavelength is simple:

$$\text{Wavelength } (\lambda) = \frac{\text{Speed of sound}}{\text{Frequency}}$$

Example:

$$\frac{\text{Speed of sound} = 344 \text{ m/s}}{\text{Frequency} = 250 \text{ Hz}} = 1.376 \text{ m (wavelength)}$$

Tones with a high frequency (many oscillations per second) have a short wavelength, tones with a low frequency accordingly have a long wavelength. A tone with a frequency of 100 Hz has a wavelength of 3.44 m, a tone of 10 000 Hz only has a wavelength of 0.0344 m. The wavelength plays an important role in sound-proofing. The longer the sound wave, the easier it is for the sound waves to penetrate solid objects such as walls, insulation and window panes.

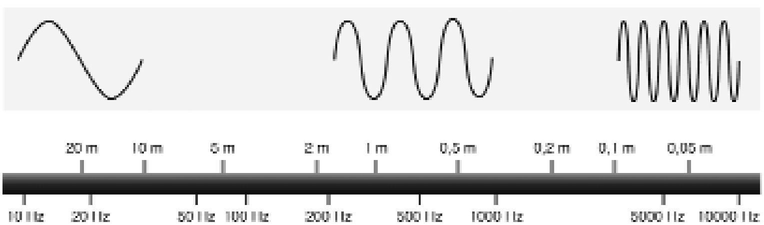

Figure 2: Frequency of an oscillation

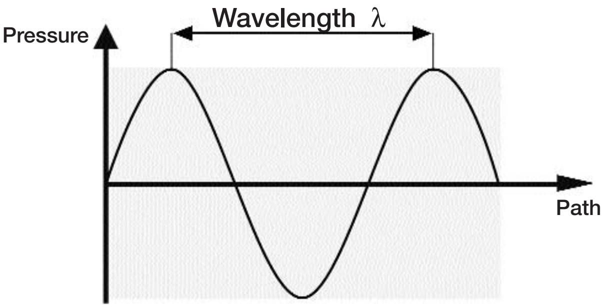

Figure 3: Wavelength

1.3 Pure tones / Frequency composition

Sound with just one frequency is described as a pure **tone**. Pure tones are sinusoidal (see above) and occur naturally very rarely. Pure tones are produced technically by so-called **frequency generators**. In everyday life, sound is composed of different tones. Even the individual tone of a musical instrument consists of many different tones, this is referred to as a complicated wave form **(frequency composition).** This type of frequency composition has a substantial effect on how we perceive the tone. Different tones and wave forms make a piano sound different from a guitar or a trumpet. Each individual human voice is different in its way. Its frequency composition only belongs to the person speaking. When we measure sound with a sound level meter, we hardly ever measure one individual tone but always a **frequency composition.**

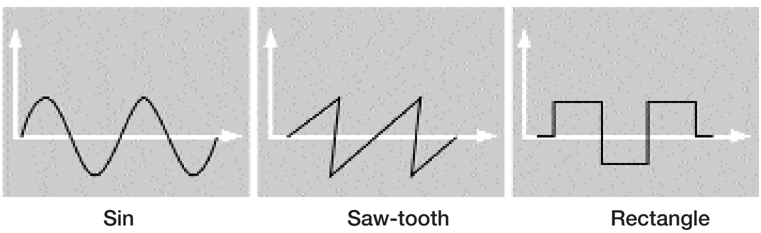

Figure 4: Example of wave forms

2. The human ear

The human ear is the sense organ which corresponds with the microphone on the sound level meter. The human ear is a particularly accurate "sound sensor", specially adapted to the requirements of the environment.

2.1 Structure

The human ear consists of three parts: the **outer ear,** the **middle ear** and the **inner ear.** The outer ear consists of the auricle and the auditory canal. The auricle gathers air sound waves like a funnel and feeds them into the auditory canal to the ear drum. Behind the eardrum, which vibrates like the skin of a drum (hence the name), is an amplifier. This amplifier consists of a hammer, anvil and stirrup. The three little hearing bones have the effect of a lever gear and pass on the sound waves to the hearing organ (the so-called cochlea). The hearing organ is a snail form duct filled with a liquid, which converts the acoustic impulses into electric nerve impulses. These are then transferrred to the brain and processed.

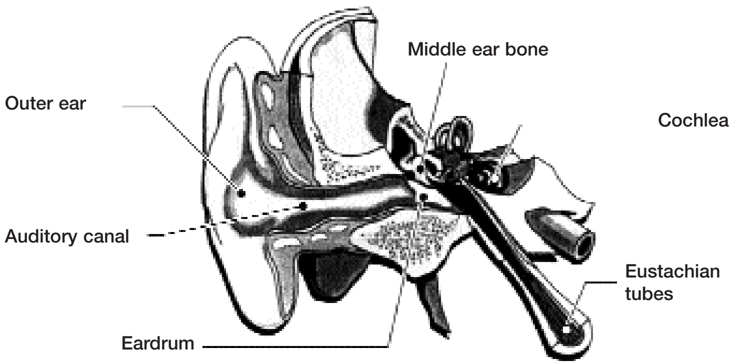

Figure 5: The human ear

2.2 Frequency response

As a result of its adaption to the environment, the ear is not equally sensitive to all frequencies. Tones below 300 Hz and tones above 5 000 Hz are, for example, perceived quieter at the same sound pressure than tones in the range 1 000 to 3 000 Hz. The subjective sensitivity of a human to how loud a tone is, is described as **loudness**. The characteristic tone from a television has a frequency of 1 000 Hz. Its sound pressure level must be much lower in order to be perceived as loudly as the sound of a car engine, for example. The sensitivity of the ear in relation to the sound level is described as the **frequency response.**

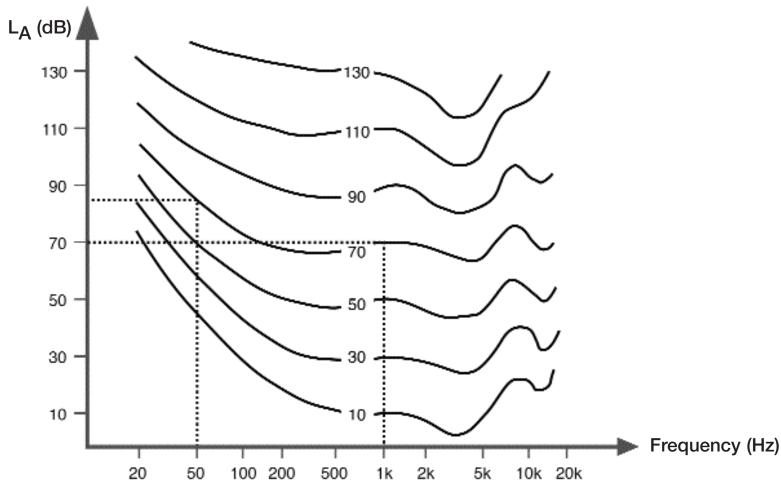

Figure 6: Curves of the same volume level

The above sketch shows lines of the same volume. This example shows that at a frequency of 1 000 Hz, a level of 70 dB is sufficient to produce the same volume as a frequency of 50 Hz at 88 dB.

The ear also has a second characteristic. Pulsating sounds, i.e. sounds which are shorter than a second, are not perceived by the ear as strongly as permanent sounds. The hammering of a typewriter, a printer or a photocopier is thus less disturbing (seen on an absolute basis) than the permanent sound of a milling machine at the same sound level. A sound level meter must take these particularities into account. The dependency of frequency of the ear must particularly be taken into consideration.

2.3 Sensitivity

The human ear is an extremely sensitive sense organ. The lowest noise detectable by the human ear produces air pressure fluctuations of only 20 µPa. The loudest noise which can be heard without pain, corresponds with pressure fluctuations of 63 Pa. This is a difference of 1: 3 000 000. This difference is described as the **volume range** of the ear.

3. Sound level

3.1 What is sound level?

As the human ear has an extremely large volume range, a list of pressure values would be unsuitable for technical data. This would result in large and awkward figures. In order to express the complete range of pressure fluctuations in manageable figures, pressure values must be replaced by level values.

Logarithmic scale values are often used in physics in order to provide a clear representation of large volume ranges. Two figures are put together as a ratio (division) and the logarithm (common logarithm) is drawn. The logarithm function is now available on all scientific calculators. In sound measuring engineering, this value is then multiplied by 20, which produces in a manageable figure. The new value is called a **decibel (dB).**

The decibel is not an absolute unit of measurement. It is based more on the relation of any measured unit to a set reference level. The reference level is 20 µPa in sound measuring engineering. It is the exit point or the so-called reference pressure.

General formula for the calculation of the sound pressure level:

$$\text{Level (dB)} = 20 \times \log \frac{P}{P_{ref}}$$

P = Sound pressure measured

P_{ref} = Reference value (20 µPa)

Example 1: Sound pressure measured: 20 000 µPa
Reference pressure level: 20 µPa

Question: How many dB does this correspond with?

$$\frac{20\,000\ \mu Pa}{20\ \mu Pa} = 1\,000$$

Answer: $\log_{10}(1\,000) = 3$ 20 x 3 = **60 dB**

Example 2: Sound pressure measured: 200 000 µPa

Reference pressure: 20 µPa

Question: Which dB level value does this correspond with?

Answer: $$\text{Level} = 20 \times \log \left(\frac{200\,000\ \mu Pa}{20\ \mu Pa} \right)$$

Level = **80 dB**

Each time we **multiply** the sound level in Pascal by 10, we add 20 dB to the level, so that 200 µPa correspond with 20 dB, 2 000 µPa with 40 dB, 20 000 µPa with 60 dB etc. The complete audible range of the human ear up to the pain level, can thus be displayed very clearly.

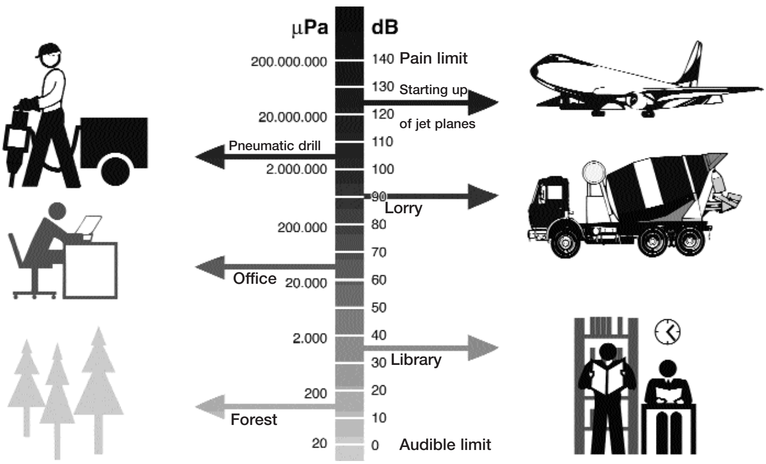

Figure 7: Comparitive scale - sound pressure to sound level

3.2 Structure of a sound level meter

A sound level meter must be built in a manner which enables it to react like a human ear in relation to frequency, and display the sound level in dB. The sound waves detected by a microphone are transferred to a weighting network via a pre-amplifier. This weighting network ensures that the instrument measures sound waves in the same manner as they are perceived by the human ear. Another amplifier sends the signal to a root mean square detector. It calculates the r.m.s. (direct voltage at equal power) from the adjoining alternating current signal and transfers this value to the instrument display via a corresponding display driver. Two **time constants,** Slow and Fast, can be selected with a special switch. The characteristics, which must be sufficient for a sound level meter, are stipulated in the DIN IEC 60651 international guideline.

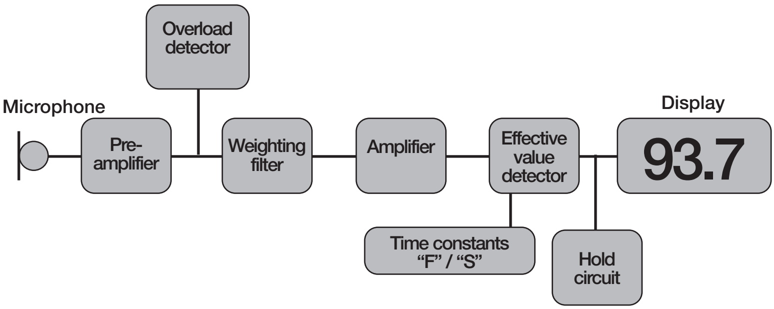

Figure 8: Schematic structure of a sound level meter

One of the most important elements of a sound level meter is the **frequency weighting network.** This network ensures that the sound level meter behaves acoustically in the same manner as the human ear. As it is not very easy to use an electronic circuit to create a network which corresponds exactly with the human ear, these characteristics are simulated by three internationally standardised curves. These are known as "A", "B" and "C" weighting. The "A" weighting processes a signal in a manner which corresponds with a reverse curve at the same sound level, in low sound pressure levels. The "B" weighting does the same in medium levels and the "C" weighting in high sound pressure levels. A special curve, which is also called the "D" weighting, was specially developed for measurements of aeroplane noise. Subjective tests (with several thousands of testers) have shown that the **“A”** weighting is the curve which corresponds best with the sound sensitivity of human beings. This is thus also referred to as **audible volumes of sound.** The **dB (A) curve** is the most commonly-used weighting curve for sound level meters in the world today. The dB (C) curve is used mostly if the low frequency levels of a noise are to be measured. If the values measured on the dB (A) and dB (C) curve deviate considerably from each other [dB (C) » dB (A)], the level of low frequency noise is considered high. In addition to one or several of these weighting curves, it is possible to send an unfiltered signal to the display for special purposes. In this case, we refer to an unweighted level measurement which is mainly indicated with **Lin** on the keyboard.

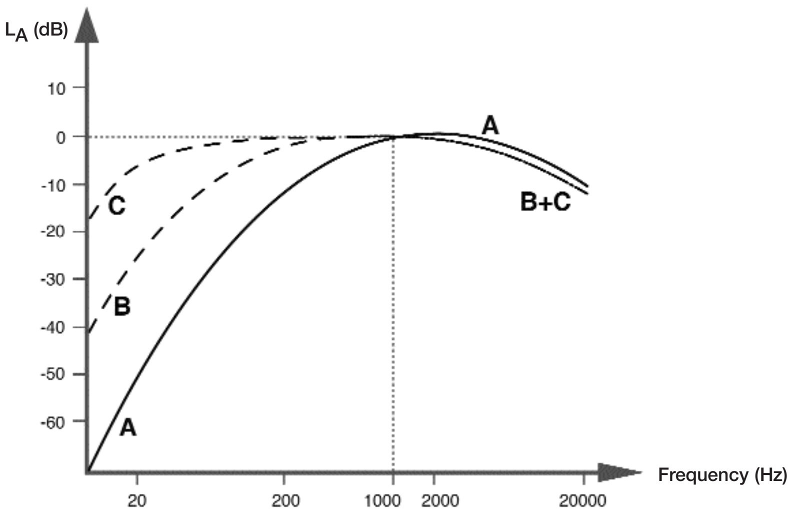

Figure 9: Sound weighting curves

3.3 The decibel as a unit of measurement

As a sound level meter displays logarithmic values, transferred via a weighting network, it is very important that this is indicated alongside the level value. The information "sound level is 65 dB" alone does not tell us very much. Was dB (A), dB (B), dB (C) or linear measurement used? The "A" and "C" frequency weightings can be selected in the Testo sound level meters, testo 815 and testo 816. Therefore, we measure dB (A) or dB (C).

It is very important that the measuring range be observed. Should the sound level be above or below this range, a warning is displayed, **"Under"** or **"Over".**

testo 815 covers the range from 32 dB A or C to 130 dB, testo 816 covers the range from 30 to 130 dB (A or C). This corresponds subjectively with the sound volume level of a library (30 to 40 dB (A)) to a starting-up of a jet aircraft (120 to 130 dB (A)). The pain limit of the human ear is between 130 and 140 dB. The ear can be permanently damaged at sound levels of over 140 dB.

3.4 Calculating with dB values

As can be seen from Figure 7, relatively small changes in dB can result in relatively large changes in sound pressure. An increase in sound of 20 dB, means an increase of ten times the sound pressure. On the other hand, this means that when two sources of sound are measured separately and are to be added to produce the total sound level, we cannot simply add both dB values together (due to logarithmic scaling).

Example:	Machine 1:	62 dB	
	Machine 2:	65 dB	
	Total level?:	62 dB + 65 dB = 127 dB?	**WRONG**

Due to the logarithmic structure of the dB scale, the values must be added together in a somewhat more complicated manner. The following formula is valid for adding sound levels (calculating the total sound level):

$$L = 10 \times \lg \left(10^{0,1 \times l1} + 10^{0,1 \times l2} + \ldots 10^{0,1 \times ln}\right)$$

For our example this would mean:

$$L = 10 \times \lg \left(10^{0,1 \times 62} + 10^{0,1 \times 65}\right)$$

$$L = 66.76 \text{ dB}$$ **RIGHT**

This means that two equally loud machines (e.g. 60 dB per machine) produce a total noise of 63 dB. On the other hand, the doubling of the sound pressure (e.g. 2 000 µPa to 4 000 µPa) represents a jump of 6 dB (in this case from 40 dB to 46 dB).

As this somewhat awkward formula is difficult to put to use in practice, a diagram exists which facilitates the work considerably. The following diagram enables the simple addition of two sound levels:

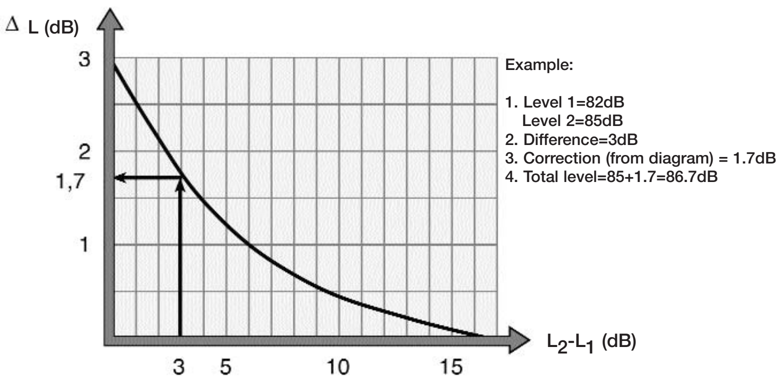

Figure 10: Addition of sound levels

In order to add two sound levels with this diagram, we proceed as follows:

1. Measure the individual sound pressure levels
2. Calculate the difference between these levels (level 2 - level 1)
3. Look for the difference between these levels on the horizontal axis of the diagram. We then go upwards until we reach the curve and then note the corresponding value on the y axis. This correction value should then be noted.
4. Add the calculated value to the larger of the two measured sound levels.

Example: Machines are measured.
Machine 1: Level = 84 dB
Machine 2: Level = 91 dB
Difference of levels: Level 2 - Level 1 = 7 dB
Correction according to diagram: 0.8 dB
Total noise: 91 dB + 0.8 dB = 91.8 dB

Addition of the same type of sound sources

If several sound sources **of the same type** are to be added, the total level can be calculated from the sum of a level plus the corresponding offset value specified in the table below.

Example: If the level of 4 sound sources of the same type are to be added together, the total level will be calculated as shown below:

$L_{tot} = L_1 + 6$ dB
Machine 1: 84 dB
Total noise: 84 dB + 6 dB = 90 dB

Number of same noise sources	2	3	4	5	6	8	10	12	14	16
Offset value for total level dB (A)	+3	+5	+6	+7	+8	+9	+10	+11	+11.5	+12

The **subtraction of sound levels** is necessary when we want to subtract disturbing background noise. Here follows the formula for the above example:

LB	=	10 x lg ($10^{0,1 \times lg}$-$10^{0,1 \times lh}$)
LB	=	Level of the sound being measured
LG	=	Total level
LH	=	Level of the background noise

Example: A milling machine is measured in a machine room. The background noise is 82 dB, the total level (measured at the machine) is 87 dB.

Question: What is the sound level of our machine (LB)?

Solution:

LB	=	10 x LG ($10^{0,1 \times 87}$ -$10^{0,1 \times 82}$)
LB	=	85.35 dB

This complicated formula can also be simplified with the use of a diagram. The procedure is similar to that of the addition of sound levels.

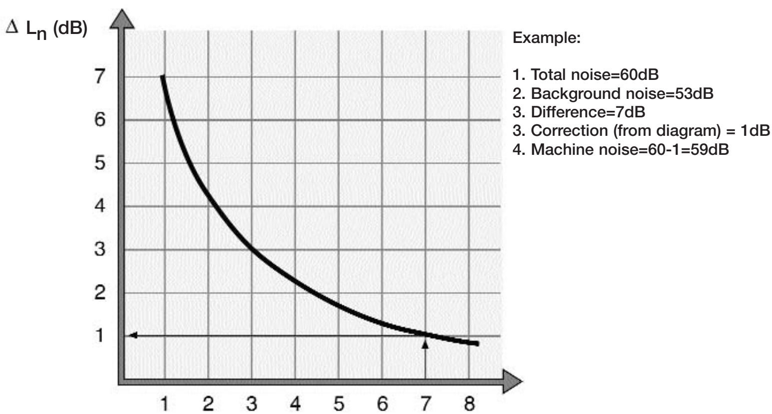

Figure 11: Subtraction of sound levels

Example: The sound level of the above-mentioned milling machine in a machine room is to be measured. As other machines are running in this room, a loud background noise is unavoidable. Measure the sound level of our machine.

1. We measure the total sound level with all machines running (our machine and all the other machines).
2. We measure the level of the background noise when our machine is switched off.
3. The difference between the total sound level and the background sound level can thus be calculated. If the difference is < 3 dB, the background level is too high for an accurate measurement. If the level is between 3 and 10 dB, correction is necessary (use the diagram). If the sound level is greater than 10 dB, correction is not required.
4. Look for the difference in sound level on the horizontal axis of the diagram, go up until you meet the curve and then left to vertical axis of the diagram. This correction value should then be noted.
5. Subtract the correction value, the value on the vertical axis, from the total noise (measured in point 1).

Our example should therefore be completed as follows:
1. Measure the total sound level (87 dB in our example).
2. Measure the background noise when the machine is switched off (82 dB in our example).
3. Difference = 87 dB - 82 dB = 5 dB. Correction is necessary.
4. Value read from diagram = Approx. 1.6 dB.
5. Subtract 1.6 dB from the total noise of 87 dB.
   87 dB - 1.6 dB = 85.4 dB.

Particularly when measuring in rooms, the reflection on surfaces, walls etc. must also be taken into consideration. The following table specifies the offset values for different positions of the sound source.

Position of sound source	Offset for increased reflection
In or directly over a reflective surface	0 db (A)
In front of two surfaces standing vertically to each other, e.g. floor in front of a wall	+ 3 dB (A)
In front of three surfaces standing vertically to each other, e.g. floor in front of an inner corner	+ 6 dB (A)

3.5 Nominal level values

A recommendation of which noise levels should be observed in which conditions and in which areas, was fixed in the TA for noise (Technical instructions). Government experts, who measure with instruments, work according to the TA.

Nominal immission values to TA:

Area	Nominal immission value dB (A)	
	Day	Night (22.00 to 6.00)
Industrial estate	70	70
Commercial estate	65	50
Town centre, industrial/housing area, village	60	45
General housing area		
Small housing estate	55	40
Purely housing estate	50	35
Health spa, hospital, home/asylum	45	35
Accommodation built directly onto factory, workshop	40	30

Nominal immission values to VDI 2058:

Area	Nominal immission value dB (A)	
	Day	Night (22.00 to 6.00)
Industrial estate (measured outside)	70	70
Commercial estate (measured outside)	65	50
Town centre, industrial/housing area, village (measured outside)	60	45
General housing area, housing estate (measured outside)	55	40
Pure housing area (measured outside)	50	35
Health spa, hospital, home/asylum (measured outside)	45	35
Appartments in all areas (measured outside)	35	25

It is common knowledge that a sound pressure level > 55 dB (A) considerably reduces concentration levels. The sound level should thus be less than 55 dB (A) in offices.

The sound levels in machine rooms and places of work differ. 55 dB (A) is valid for intellectual or mainly intellectual work. With machine work, it is dangerous for the sound level to reach or exceed a permanent, assessed level of 85 dB (A) or an unweighted level of 140 dB. The assessed level is an 8 hour constant noise or the mean level between timed fluctuating levels. Special noise dose meters are available for this purpose. They add different sound levels over a period of several hours. When measuring with the testo 815 sound level meter, a sound level of 85 dB is not to be exceeded for long periods in a machine room. When the following sound pressure levels come into effect for the following periods of time, an assessed level of 85 dB (A) has already been achieved:

88 dB (A) – 4 hours
91 dB (A) – 2 hours
94 dB (A) – 1 hour
97 dB (A) – 30 minutes
100 dB (A) – 15 minutes
105 dB (A) – 4.8 minutes

For other environments and activities, the following values serve as a rough approximation:

- Work involving mainly intellectual activities: 55 dB (A)
- Simple work or mainly mechanical office activities or equivalent activities: 70 dB (A)
- All other activities: <85 dB (A)
- Recreation rooms, stand-by area, sanitary rooms max. 55 dB (A)

How are measurements carried out?

Conditions	Conditions of measurement
Unbuilt area on the edge of works site, can however be built-up*	3 m from the edge of the site, 1.2 m above the ground
Adjacent area with buildings*	0.5 m in front of the most badly affected window
Building* without window	Inside building
Building not directly surrounded	3 m from the edge of the property 1.2 m high
Rooms*, directly connected to industrial workshops	Windows closed, in 1.2 m from floor, windows and walls. Windows and doors closed
Measurement in offices	Measurements in places in which noise, plays an important role, e.g. at a work desk, 1.2 m above the ground. Microphone directed towards the source of the noise.
Measurements in work rooms	Either at the place of immission (place at which enters room) or directly at the machine producing noise.

* designed for accommodation of people.

4. Engineering / DIN IEC 60651

4.1 Frequency weighting

In order to assess the sound signals in a manner which corresponds with the human auditory canal, frequency weighting is carried out. As we saw in Figure 9, the following sound weighting curves exist: A, B, C and D. The DIN IEC 60651 contains a table which features the changes in level with the different weighting curves. The A and C weightings are valid for the testo 815/816 instruments. Here follows a short extract of this table (for several important frequencies):

Nom. frequency in Hz	A weighting	B weighting	C weighting
10	-70.4	-38.2	-14.3
20	-50.5	-24.2	-6.2
50	-30.2	-11.6	-1.3
100	-19.1	-5.6	-0.3
250	-8.6	-1.3	-0.0
500	-3.2	-0.3	0.0
1 000	0.0	0.0	0.0
2 000	+1.2	-0.1	-0.2
2 500	+1.3	-0.2	-0.3
5 000	+0.5	-1.2	-1.3
8 000	-1.1	-2.9	-3.0
10 000	-2.5	-4.3	-4.4
20 000	-9.3	-11.1	-11.2

How are these values to be interpreted?

Example: An instrument with the sound weighting curve A shows 19.1 dB less, at 100 Hz, than if the signal had not been weighted. All three curves are only unweighted at a frequency of 1 000 Hz. That means that the signal is transmitted without filtering.

4.2 Time weighting

In order to ensure that the signal is adapted in the best possible way to changing tone fluctuations, different time weightings have been planned in the DIN IEC 60651. The following can be found in point 4.5, under general features:

The frequency-weighted signal is unidirected and displayed; the signal is time-weighted with the help of one of the S, F, I and "peak" ("PEK") characteristics. Sound level meters can be fitted with several of these time weightings; they must however be fitted with at least one of the time weightings F and S. The "peak" time weighting allows the measurement of the absolute peak value of an acoustic signal. The time constants are stipulated as follows:

Time weighting F: Time constant = 125 mS

Time weighting S: Time constant = 1 000 mS (1 second)

4.3 Classes of instruments

Sound level meters are generally subdivided into 4 classes. They can in principle only be distinguished by their accuracy.

Class 0	Class 1	Class 2	Class 3
± 0.4 dB	± 0.7 dB	± 1.0 dB	± 1.5 dB

This information on classes is valid for a working temperature range of -10 to +50 °C. Instruments which operate in one of the limited ranges (e.g. 0 to 40 °C) are indicated with an L (e.g. class 2L, class 3L etc.).

The following can be read in DIN IEC 60651:

"A device must be available which can be used to control, and if necessary correct, the calibration of the instrument for the reference frequency".

Note: This is possible with our calibrator (accessory).

The frequency range of a class 3 instrument covers 31.5 Hz to 8 000 Hz.

4.4 Storage of the maximum value

The IEC guideline recommends the following:

“Sound level meters with numerical display or another discontinuous display must have at least one type of operation, in which the maximum value of the weighted sound level is stored at a measuring interval ...”.

The testo 815/816 sound level meters have a maximum and minimum value memory. The function operates as follows: once the “Max/Min” key has been pressed, the sound level value is held in display. Each level which is larger than the last displayed value is displayed. This therefore provides a real maximum value display. If the “Max/Min” is pressed again, the minimum value is shown. The smallest sound level measured is shown in this mode. Each level which is lower than the last one in the display is shown. Once the Max/Min button is pressed again, the instrument is then in Max/Min mode i.e. the current value is shown, the maximum and minimum value is saved and shown by pressing the max/min key. It takes minimum 3 seconds to get to the normal measurement mode by pressing the max/min key. By returning to the normal measuring mode, the storage of maximum values is erased. Should the “Max” key be pressed once again, the instrument returns to the maximum value storage mode, ready for a new measurement of the maximum sound level.

4.5 Frequency analysis

Some special sound level meters are fitted with so-called frequency analysis modules. The testo 815/816 do not belong to this group, however a filter module for frequency analysis may be conceivable with later products. When the user of the instrument wants to know which sound level occurs at which frequency, a frequency analysis module is used. These modules are usually connected to the instrument, and filter the input signal in such a manner that only certain frequencies are displayed. In acoustics, so-called **bandpass filters** are used. These filters let certain frequencies through, while all other frequencies are held back.

Technically-speaking, it is not possible to just let one frequency through the filter. A filter always lets a certain number of frequencies through. The reference frequency of the filter, i.e. the frequency which can press through the filter without any loss, is called the midband frequency. With a sound level of -3 dB, we can find two frequency points to the left and the right (on a graph), the so-called **corner frequencies** of the filter. The mid-band frequency is called f_0, the lower corner frequency f_{gu} and the upper corner frequency f_{go}. The difference (in Hz) between the upper and lower **corner frequencies** is called the band-width of a filter.

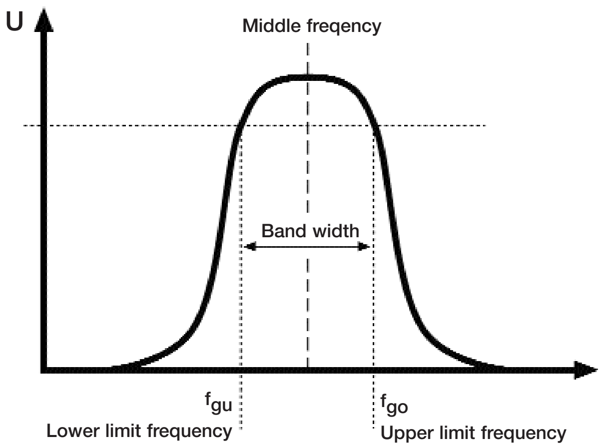

Figure 12: Characteristics of a band filter

Frequency analysis is necessary in order to examine sources of noise, to anticipate insulating characteristics of sound-absorbing walls and panelling or to measure sound insulation of housing walls. Two different systems are used: **octave band filter** and **third octave band filter.**

4.5.1 Octave band filtration

In order to subdivide a frequency range (for example 30 Hz to 8 000 Hz) in **frequency bands**, we need several filters. These filters should be evenly spaced. It is possible to space the medium frequency of the different filters at intervals of an octave. One octave corresponds physically with **double the frequency.**

Example: Frequency 1 = 60 Hz
Increase in octave: F 2 = 120 Hz

Each further doubling of this figure corresponds with one octave (this is the same octave we know in music). With sound level metres, we begin as a rule with the lowest medium frequency of 31.5 Hz and end (depending on the instrument class) at 8 to 16 Hz. The medium frequencies of the third-octave band filter are as follows:

31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz
1 000 Hz	2 000 Hz	4 000 Hz	8 000 Hz	16 000 Hz

In order to analyse the sound, the source of noise is examined with the different filters one after the other (this function operates partly automatically). What we then receive is a "bar chart" of level values. The diagram could, for example, look like this:

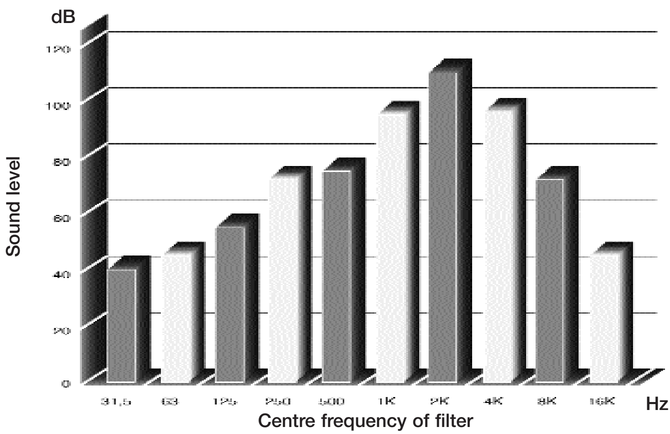

Figure 13: Frequency diagram with octave analysis

The highest bar in this diagram shows us the frequency, which was recorded as being the loudest. When taking sound-proofing measures, it is only worth trying to find a means of insulating this particular frequency. When analysing a household instrument, a car or a similar object, the different sound levels come from different **sources of noise**. For example with a car: engine, vibrations from the car body, noise from the gear box, differential noise, rolling of tyres. Should the user determine that the sound of the engine is the main source of noise at a certain speed, active insulating measures can be carried out before effecting another frequency analysis.

4.5.2 Third octave band filtration

Should you require a smaller subdivision of the frequency bands, you must fall back on third-octave analysis. This means that each frequency band of the octave analysis is divided into three. The medium frequencies of the third-octave band filter are as follows:

31.5 Hz,	40 Hz,	50 Hz,	63 Hz,	80 Hz,
100 Hz,	125 Hz,	160 Hz,	200 Hz,	250 Hz,
315 Hz,	400 Hz,	500 Hz,	630 Hz,	800 Hz,
1 kHz,	1.25 kHz,	1.6 kHz,	2 kHz,	2.5 kHz,
3.15 kHz,	4 kHz,	5 kHz,	6.3 kHz,	8 kHz,
10 kHz,	12.5 kHz,	16 kHz.		

As can be seen, the frequencies of the octave analyis reappear with third-octave analysis. The gap between two of these octave frequencies is filled with two further frequencies. A diagram, recorded with a third-octave analysis module, would appear as follows:

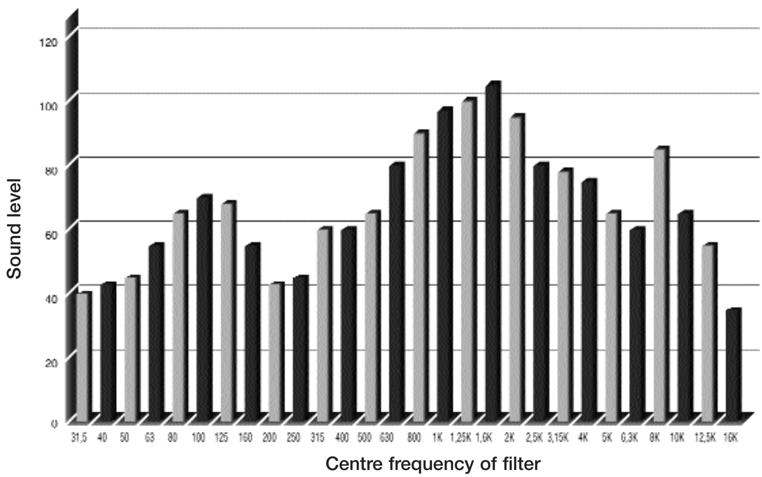

Figure 14: Frequency diagram with third-octave analysis.

5. Handling

Sound has the unpleasant characteristic of reflecting on walls, ceilings and on the body of the user. When not used correctly, measuring errors can occur. Certain points must therefore be observed when using sound level meters.

5.1 Holding the microphone

According to the DIN/IEC guideline, a sound level meter must be placed at an angle of 0° in relation to the source of the noise. This means that the microphone must be pointed directly at the source of noise.

Figure 15: Positioning of the microphone according to DIN/IEC

Figure 16: Handling the microphone

The instrument housing and the presence of the operator cannot only obstruct the sound, coming from a certain direction, but also cause reflections and thus considerable measuring errors. Experiments have shown that at frequencies of 400 Hz, errors of up to 6 dB can be caused if the measurement is carried out less than one metre from the body. This error is smaller with other frequencies, however a minimum distance should be observed. It is advisable to keep the microphone at least 30 cm - even better 50 cm - from the body.

5.2 Free field / Diffuse field

Ideal measuring conditions can always be obtained when no objects obstruct the field of noise. This condition would, for example, arise outside on a mountain top. The microphone would be attached to a stand and the user would be several metres away. As there are no walls or ceilings on which the sound can be reflected, a free diffusion of sound is guaranteed.

These measuring conditions are known technically as the **free field.** In daily practice, reflections on ceilings, walls and other objects can be just as strong as direct sound and accurate measurements are not possible. This is called the **diffuse field.**

Sound level meters are normally developed for measurements in the free field. A free field is also granted if the sound level drops by **6 dB** each time the **distance from the source doubles**. This is the case in most rooms.

Example:

Offices with carpets, curtains and dividers = free field

Cellars with cement walls, without furniture, resounding = diffuse field.

5.3 Near field error during measurement

Should you measure the sound level of machines, the sound pressure level can alter considerably with a slight change in the position of the sound level meter. This occurs particularly at a distance of less than the wavelength of the lowest frequency, sent by the machine. The field in the immediate proximity of a source of noise is known as the **near field.** Measurements in this area should be avoided when possible. The distance should be at least 1 m, even better 2 m, from the producer of noise. In a closed room, for example, a wall is opposite the source of noise. This can cause reflections, which produce incorrect measuring results. This field is called the **reverberant field.**

Measurements with a sound level meter should be carried out outside the near field. The area outside the near field (free field or reverberant field) is known as the **distant field**.

5.4 Calibration

According to DIN IEC 60651, section 4, a device must be available which can be used to control, and if necessary correct, the calibration of the instrument for the reference frequency. This is possible with the calibrator (see Fig. 17) for testo 815/816. The calibrator produces a highly-constant tone of 1 000 Hz at the levels 94 dB or 104 dB. 94 dB is usually used as a reference level. The microphone is inserted into the calibrator (94 dB) and then the instrument is switched on. The adjustment screw for the level can be adjusted, using the calibration screw driver, such that 94.0 dB appears in the display. Calibration is now complete.

Ideally the measuring instrument should be calibrated before and after a measurement in order to note changes. Calibration should however take place at least once a week, or twice a week, when regular measurements are carried out. If the instrument is not used for a longer period, calibration must be carried out before starting a measurement.

Figure 17: Calibrating testo 815/816 with a calibrator

6. Appendix

6.1 Technical data for testo 815/816

Probe	Accurate electret condensator microphone, 1/2 inch
Total measuring range	30 to 130 dB(A) / dB (C)
Part measuring ranges	30 (32) to 80 / 50 to 100/ 80 to 130 dB (A) / dB (C)
Time settings	
FAST	125 ms
SLOW	1 s
Accuracy ±1 digit	±1.5 dB(A) in reference conditions
Pressure drift	-1.6 x 10^{-3} dB/hPa
Resolution	0.1 dB(A)
Display	LCD
Battery life	815: 70 h / 816: 50 h
Operating temperature	0 to +40 °C
Storage/transport temperature	-20 to +60 °C
Housing material	ABS
Frequency weighting	A/C

6.2 Absolute pressure drift

A difference in altitude of the place of measurement can influence the pressure drift of the measuring result. Suitable correction measures can eliminate this error.

Note: If the instrument is calibrated just before the measurement (in line with the correction values for the calibrator) the following table should **not** be used.

Height in masl	Pressure p/mbar	Correction dB
0	1013	0.0
100	1001	-0.0
200	990	-0.0
300	978	-0.1
400	966	-0.1
500	955	-0.1
600	944	-0.1
700	932	-0.1
800	921	-0.1
900	910	-0.2
1000	899	-0.2
1100	889	-0.2
1200	**878**	**-0.2**
1300	**868**	**-0.2**
1400	**858**	**-0.2**
1500	**847**	**-0.3**

Example: Location at 500 m above sea level

Value displayed:	67.8 dB(A)
Offset value:	-0.1 dB(A)
Offset value:	67.1 dB(A)

6.3 Technical data for calibrator

Principle of function	Quarz-controlled oscillator with a middle frequency of 1000 Hz at the precision speaker Pressure chamber with input opening for testo 815/816 microphone
Sound pressure level	94 dB(A) / 104 dB(A) (adjustable)
Frequency	1000 Hz
Distortion factor	<3%
Battery	9V block (6F 22)
Battery life	25 h (alkali manganese)
Battery warning	A red LED warns of a low battery voltage

6.4 Correction of pressure drift

A slight pressure drift caused by the height above sea level can be corrected with the following table. The value displayed on the measuring instrument does not need to be corrected (see 6.2) if the instrument was calibrated before the measurement.

Height in m above sl	Pressure in mbar	Nom val. during cal. 94 dB	104 dB
0	1013	94.0	104.0
100	1001	94.0	104.0
200	990	94.0	103.9
300	978	93.9	103.9
400	966	93.9	103.9
500	955	93.9	103.9
600	944	93.9	103.9
700	932	93.9	103.9
800	921	93.9	103.9
900	910	93.8	103.8
1000	899	93.8	103.8
1100	889	93.8	103.8
1200	878	93.8	103.8
1300	868	93.8	103.8
1400	858	93.8	103.8
1500	847	93.7	103.7

Height in m above sl	Pressure in mbar	Nom val. during cal. 94 dB	104 dB
1600	837	93.7	103.7
1700	827	93.7	103.7
1800	816	93.7	103.7
1900	806	93.7	103.7
2000	796	93.7	103.7
2100	786	93.6	103.6
2200	777	93.6	103.6
2300	768	93.6	103.6
2400	758	93.6	103.6
2500	749	93.6	103.6
2600	739	93.6	103.6
2700	730	93.5	103.5
2800	721	93.5	103.5
2900	711	93.5	103.5
3000	702	93.5	103.5

Example:	Height of place of meas.:	500 m above s.l.
	Offset value:	-0.1 dB(A)
	Adjustable value:	93.9 dB(A)

During calibration, the exact reference level (usually 94.0 dB) is not set in the instrument, but rather the value listed in the correction table. When comparing the second correctional level (e.g. 104.0 dB), please note that the correctional value should also be used.

Notes

Notes

Notes

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Suggestion(s) for improvement / Request for product information

To:

Sender:

Name ______________________

Department ______________________

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Telephone ______________________

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Date, Signature ______________________

☐ I would like more information on the following products:

☐ Sound level measurement from 30 to 130dB (Part no. 0981 0754)

☐ Luxmeter with site management and mean calculation (Part no. 0981 1984)

☐ Industry Measurement Engineering (Part no. 0981 0194)

☐ Measurement Engineering for Heating and Installation (Part no. 0981 0274)

We are grateful for all suggestions for improvement in order to keep this Sound handbook up to date and meet the requirements in the field.

☐ I have the following suggestion(s) for improvement:

Chap.		Page	Topic Suggestion

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