

D. DEFINITIONS AND FILTER CHARACTERISTICS

D.1. Definitions and formulae

D.1.1. Definitions and formulae of the results measured in DOSE METER mode

Basic symbols and notation

- T** - current period of the measurement
- T_b** - period after which the results are saved in the logger set in the **LOGGER STEP** (*path: MENU / INPUT / MEASUREMENT SETUP / LOGGER STEP*)
- T_c** - period of the measurement set in the **INTEGR. PERIOD** (*path: MENU / INPUT / MEASUREMENT SETUP / INTEGR. PERIOD*)
- T_e** - exposure time (period during which a person is exposed to the action of noise). This parameter can be set in the **EXPOSURE TIME** (*path: MENU / SETUP / EXPOSURE TIME*). The available values are from 1 minute to 8 hours with 1-minute step.
- T_{8h}** - period equal to 8 hours (28 800 seconds)
- τ** - detector time-constant set in the **DETECTOR** (*path: MENU / INPUT / PROFILE (x) / DETECTOR*). The available values are equal to **IMPULSE**, **FAST** or **SLOW**
- a_w(t)** - the temporary value of the measured sound with the weighting filter **W** (equal to **A** for PROFILE 1, **C** for PROFILE 2 and **Z** for PROFILE 3) on the input of the RMS detector
- p_w(t)** - the temporary value of the measured sound with the weighting filter **W** (equal to **A** for PROFILE 1, **C** for PROFILE 2 and **Z** for PROFILE 3) (equal to **A**, **C** or **Z**, *path: MENU / INPUT / PROFILE x / FILTER*) on the output of the RMS detector calculated from the equation:

$$p_w(t) = \left(\frac{1}{\tau} \int_{-\infty}^t a_w^2(t_x) \exp\left(\frac{t_x - t}{\tau}\right) dt_x \right)^{1/2}$$

where:

- t_x** - time (variable of the integration)
- p₀** - the reference value equal to 20 μPa
- Q** - the exchange rate in decibels equal to **2**, **3**, **4** or **5** and set in the **EXCHANGE RATE** (*path: MENU / INPUT / DOSE METER SETUP / EXCHANGE RATE*). The value of **Q** influences the calculations of dose meter results, namely **DOSE**, **D_{8h}** and **LAV**. The exposure rate equal to 3 complies with ISO R 1999 "Assessment of Occupational Noise Exposure for Hearing Conservation Purposes", while **Q** equal to 5 complies with the American "Occupational Safety and Health Act" – OSHA. The value of **q** used in the calculations of **DOSE**, **D_{8h}** and **LAV** is taken from the formula:

$$q = \begin{cases} \frac{Q}{\log 2} & \text{for } Q \neq 3 \\ 10 & \text{for } Q = 3 \end{cases}$$

- L_T** - the threshold sound level set in the **THRESHOLD LEVEL** (*path: MENU / INPUT / DOSE METER SETUP / THRESHOLD LEVEL*). The available values are as follows: **None**, **75 dB**, **80 dB**, **85 dB** or **90 dB**

L_c - the criterion sound level set in the **CRITERION LEVEL** (*path: MENU / INPUT / DOSE METER SETUP / CRITERION LEVEL*). The available values are as follows: **80 dB, 84 dB, 85 dB** or **90 dB**

$L(t)$ - sound level (a function of time) measured with the selected time-constant (**IMPULSE, FAST** or **SLOW**; *path: MENU / INPUT / PROFILE x / FILTER*) and the weighting filter (equal to **A**) calculated from the formula:

$$L(t) = 20 \log \frac{p_w(t)}{p_0}$$

$L_d(t)$ - sound level (a function of time), depends on the selected threshold level. In the case when the **None** option was selected:

$$L_d(t) = L(t)$$

In the other cases (when the **THRESHOLD LEVEL** (*path: MENU / INPUT / DOSE METER SETUP / THRESHOLD LEVEL*) is equal to **75 dB, 80 dB, 85 dB** or **90 dB**) this sound level is taken from the formula:

$$L_d(t) = \begin{cases} L(t) & \text{for } L(t) \geq L_T \\ -\infty & \text{for } L(t) < L_T \end{cases}$$

DOSE result

The **DOSE** result is the quantity of noise received by the worker, expressed as the percentage of the whole day acceptable value. This result is calculated from the formula:

$$DOSE = \frac{100\%}{T_{8h}} \int_0^T 10^{\frac{L_d(t)-L_c}{q}} dt$$

D_8h result

The **D_8h** result is the quantity of noise received by the worker during 8 hours. This result is calculated from the formula:

$$D_{8h} = \frac{100\%}{T} \int_0^T 10^{\frac{L_d(t)-L_c}{q}} dt = \frac{T_{8h}}{T} \cdot DOSE$$

LEPd result

The **LEPd** result (Exposure level related to 8-hours working day expressed in dBA) is calculated on the base of the **LEQ** from the formula:

$$LEPd = LEQ + 10 \cdot \log \frac{T_e}{T_{8h}}$$

LAV result

The **LAV** result is the average level of the acoustic pressure for the given time period of the measurement. This result is calculated from the formula:

$$LAV = q \cdot \log \left(\frac{1}{T} \int_0^T 10^{\frac{L_d(t)}{q}} dt \right)$$

In the case of **Q** (the exchange rate) equal to 3 the **LAV** result has the same value as **LEQ** (if the **EXPONENTIAL** option is selected in the **RMS INTEGRATION** (path: MENU / SETUP / RMS INTEGRATION)).

LEQ function

The **LEQ** function enables the user to calculate the RMS value of sound pressure in the given time period. It is counted with A weighting filter. The instrument operates as the standard **Integrating Sound Level Meter** and conforms to the **IEC 804 Standard** (meeting the requirements for **Type 2** instrument). The value of the **LEQ** function is calculated, when the **LINEAR** option is selected in the **RMS INTEGRATION** (path: MENU / SETUP / RMS INTEGRATION), according to the formula:

$$LEQ = 20 \log \left(\frac{1}{T} \int_0^T (a_w(t)/p_0)^2 dt \right)^{1/2}$$

The value of the **LEQ** function is calculated, when the **EXPONENTIAL** option is selected in the **RMS INTEGRATION** (path: MENU / SETUP / RMS INTEGRATION), according to the formula:

$$LEQ = 20 \log \left(\frac{1}{T} \int_0^T (p_w(t)/p_0)^2 dt \right)^{1/2}$$

In the case the **LEQ** value saved as the main result **T = T_c**.



Note: For **T = T_b** the **LEQ** values are saved in the files of the logger (time-history) as the **RMS** results (see below).

PEAK value

The **PEAK** value (Peak Sound Pressure or Peak Sound Level) depends on the weighting filter **W** (equal to **A**, **C** or **Z**) and is calculated for the given **T** from the formula:

$$PEAK = 20 \log \left(\max_T \left| \frac{a_w(t)}{p_0} \right| \right)$$

In the case of the **PEAK** value saved as the main result **T = T_c**. When the **PEAK** value is saved in the files of the logger (time-history) - **T = T_b**.

MAX result

The **MAX** result means the maximal value on the detector output for the integration period. The **MAX** result for the period of 1 second is equal to the value of the **SPL** function. The **MAX** result is calculated according to the formula:

$$MAX = 20 \log \left(\max_T \frac{p_w(t)}{p_0} \right)$$

In the case of the **MAX** value saved as the main result **T = T_c**. When the **MAX** value is saved in the files of the logger (time-history) - **T = T_b**.

E result

The **E** result (Exposition) represents the amount of the acoustical energy received by the worker. The **E** value is calculated according to the formula:

$$E = \frac{T[s]}{3600} p_0^2 \cdot 10^{\frac{LEQ}{10}}$$

The **E** result is expressed in the linear units (Pa²h).

SEL result

The **SEL** result (Sound Exposure Level) is essentially the subset of the **LEQ** function. Its value is equal to the **LEQ result referred to the integration time equal to one second** (so, for the **INT. TIME=1 s**, **SEL** is always equal to **LEQ**). The value of the **SEL** function is calculated, when the **LINEAR** option is selected (*path: MENU / SETUP / RMS INTEGRATION*), according to the formula:

$$SEL = 20 \log \left(\int_0^T (a_w(t)/p_0)^2 dt \right)^{\frac{1}{2}} = LEQ + 10 \cdot \log \frac{T[s]}{1[s]}$$

The value of the **SEL** function is calculated, when the **EXPONENTIAL** option is selected (*path: MENU / SETUP / RMS INTEGRATION*), according to the formula:

$$SEL = 20 \log \left(\int_0^T (p_w(t)/p_0)^2 dt \right)^{\frac{1}{2}} = LEQ + 10 \cdot \log \frac{T[s]}{1[s]}$$

In the case of the **SEL** value saved as the main result **T = T_c**. The **SEL** value is not saved in the files of the logger (time-history).

E_8h result

The **E_8h** result (Exposition in 8 hours) represents the amount of the acoustical energy received by the worker during 8 hours. The **E_8h** value is calculated according to the formula:

$$E_{8h} = 8[h] \cdot p_0^2 \cdot 10^{\frac{LEQ}{10}}$$

The **E_8h** result is expressed in the linear units (Pa²h).

SEL8 result

The **SEL8** result is the **SEL result corresponding to the integration time equal to 8 hours**. The **SEL8** result is calculated on the base of the **LEQ** according to the formula:

$$SEL8 = LEQ + 10 \cdot \log \frac{T_{8h}[s]}{1[s]}$$

PSEL result

The **PSEL** result (individual Sound Exposure Level to the noise) is equal to the standing sound level in a measurement period. The **PSEL** result is calculated on the base of the **LEQ** according to the formula:

$$\text{PSEL} = \text{LEQ} + 10 \cdot \log \frac{T}{T_{8h}}$$

PCTC result

The **PCTC** result (**PEAK C THRESHOLD COUNTER**) – the number of the overpasses of the THRESHOLD LEVEL by PEAK_C result (PEAK counted with C weighting filter). This result is incremented in 100 ms intervals.

PCTP result

The **PCTP** result is the **PCTC** result expressed in percents, according to the formula:

$$\text{PCTP} = \frac{100 \cdot \text{PCTC}}{10T_c}$$

RMS result

The **RMS** result, saved in the logger's file, is calculated according to the formula of the **LEQ** function. The value of the **RMS** result is calculated, when the **LINEAR** option is selected in the **RMS INTEGRATION** (*path: MENU / SETUP / RMS INTEGRATION*), according to the formula:

$$\text{RMS} = 20 \log \left(\frac{1}{T_b} \int_0^{T_b} (a_w(t)/p_0)^2 dt \right)^{1/2}$$

The value of the **RMS** result is calculated, when the **EXPONENTIAL** option is selected in the **RMS INTEGRATION** (*path: MENU / SETUP / RMS INTEGRATION*), according to the formula:

$$\text{RMS} = 20 \log \left(\frac{1}{T_b} \int_0^{T_b} (p_w(t)/p_0)^2 dt \right)^{1/2}$$

D.1.2. Definitions and formulae in Sound Level Meter**Basic symbols and notation**

- T** - current period of the measurement
- T_b** - period after which the results are saved in the logger set in the **LOGGER STEP** (*path: MENU / INPUT / MEASUREMENT SETUP / LOGGER STEP*)
- T_c** - period of the measurement set in the **INTEGR. PERIOD** (*path: MENU / INPUT / MEASUREMENT SETUP / INTEGR. PERIOD*)
- T_e** - exposure time (period during which a person is exposed to the action of noise). This parameter can be set in the **EXPOSURE TIME** (*path: MENU / SETUP / EXPOSURE TIME*). The available values are from 1 minute to 8 hours with 1-minute step.
- T_{8h}** - period equal to 8 hours (28 800 seconds)

- τ - detector time-constant set in the **DETECTOR** (*path: MENU / INPUT / PROFILE (x) / DETECTOR*). The available values are equal to **IMPULSE**, **FAST** or **SLOW**
- $a_w(t)$ - the temporary value of the measured sound with the weighting filter **W** (equal to **A**, **C** or **Z**, *path: MENU / INPUT / PROFILE x / FILTER*) on the input of the RMS detector
- $p_w(t)$ - the temporary value of the measured sound with the weighting filter **W** (equal to **A**, **C** or **Z**, *path: MENU / INPUT / PROFILE x / FILTER*) on the output of the RMS detector calculated from the equation:

$$p_w(t) = \left(\frac{1}{\tau} \int_{-\infty}^t a_w^2(t_x) \exp\left(-\frac{t_x - t}{\tau}\right) dt_x \right)^{1/2}$$

where:

t_x - time (variable of the integration)

p_0 - the reference value equal to 20 μ Pa

SPL function

The **SPL** function (**Sound Pressure Level**) - gives an equivalent of the **Sound Level Meter** according to the **IEC 651 Standard** (meeting the requirements for the **Type 2** instrument). The value of the functions depends on the weighting filter **W** (equal to **A**, **C** or **Z**; *path: MENU / INPUT / PROFILE x / FILTER*) and is calculated from the formula:

$$\text{SPL} = 20 \log \left(\max_{T_1} \frac{p_w(t)}{p_0} \right)$$

where:

T_1 - the last second of the measurement

LEQ function

The **LEQ** function enables the user to calculate the RMS value of sound pressure in the given time period. The instrument operates as the standard **Integrating Sound Level Meter** and conforms to the **IEC 804 Standard** (meeting the requirements for **Type 2** instrument). The value of the **LEQ** function is calculated, when the **LINEAR** option is selected in the **RMS INTEGRATION** (*path: MENU / SETUP / RMS INTEGRATION*), according to the formula:

$$\text{LEQ} = 20 \log \left(\frac{1}{T} \int_0^T (a_w(t)/p_0)^2 dt \right)^{1/2}$$

The value of the **LEQ** function is calculated, when the **EXPONENTIAL** option is selected in the **RMS INTEGRATION** (*path: MENU / SETUP / RMS INTEGRATION*), according to the formula:

$$\text{LEQ} = 20 \log \left(\frac{1}{T} \int_0^T (p_w(t)/p_0)^2 dt \right)^{1/2}$$

In the case the **LEQ** value saved as the main result $T = T_c$.



Note: For $T = T_b$ the **LEQ** values are saved in the files of the logger (time-history) as the **RMS** results (see below).

SEL result

The **SEL** result (Sound Exposure Level) is essentially the subset of the **LEQ** function. Its value is equal to the **LEQ result referred to the integration time equal to one second** (so, for the **INT. TIME=1 s**, **SEL** is always equal to **LEQ**). The value of the **SEL** function is calculated, when the **LINEAR** option is selected (*path: MENU / SETUP / RMS INTEGRATION*), according to the formula:

$$\text{SEL} = 20 \log \left(\int_0^T (a_w(t)/p_0)^2 dt \right)^{1/2} = \text{LEQ} + 10 \cdot \log \frac{T[s]}{1[s]}$$

The value of the **SEL** function is calculated, when the **EXPONENTIAL** option is selected (*path: MENU / SETUP / RMS INTEGRATION*), according to the formula:

$$\text{SEL} = 20 \log \left(\int_0^T (p_w(t)/p_0)^2 dt \right)^{1/2} = \text{LEQ} + 10 \cdot \log \frac{T[s]}{1[s]}$$

In the case of the **SEL** value saved as the main result $T = T_c$. The **SEL** value is not saved in the files of the logger (time-history).

Ld, Le, Ln, Lde, Len, Lnd and Lden results

Only one from the mentioned above results is contextually available in the instrument. It depends on the day and nighttime in which the measurement was performed. It is assumed that:

- the day-time (denoted as T_d) starts from 6 am and ends at 6 pm or starts from 7 am and ends at 7 pm,
- the evening-time (denoted as T_{ev}) starts from 6 pm and ends at 10 pm or starts from 7 pm and ends at 11 pm,
- the nighttime (denoted as T_n) starts from 10 pm and ends at 6 am or starts from 11 pm and ends at 7 am.

The mentioned above results are calculated from the following formulae:

$$\text{Ld} = 20 \log \left(\frac{1}{T_d} \int_{T_d} (r_w(t)/p_0)^2 dt \right)^{1/2} \quad (T_d \neq 0, T_{ev} = 0, T_n = 0)$$

$$\text{Le} = 5 \text{ dB} + 20 \log \left(\frac{1}{T_{ev}} \int_{T_{ev}} (r_w(t)/p_0)^2 dt \right)^{1/2} \quad (T_d = 0, T_{ev} \neq 0, T_n = 0)$$

$$\text{Ln} = 10 \text{ dB} + 20 \log \left(\frac{1}{T_n} \int_{T_n} (r_w(t)/p_0)^2 dt \right)^{1/2} \quad (T_d = 0, T_{ev} = 0, T_n \neq 0)$$

$$\text{Lde} = 10 \log \left[\frac{1}{12+4} (12 \cdot 10^{\text{Ld}/10} + 4 \cdot 10^{\text{Le}/10}) \right] \quad (T_d \neq 0, T_{ev} \neq 0, T_n = 0)$$

$$\text{Len} = 10 \log \left[\frac{1}{4+8} (4 \cdot 10^{\text{Le}/10} + 8 \cdot 10^{\text{Ln}/10}) \right] \quad (T_d = 0, T_{ev} \neq 0, T_n \neq 0)$$

$$\text{Lnd} = 10 \log \left[\frac{1}{8+12} (8 \cdot 10^{\text{Ln}/10} + 12 \cdot 10^{\text{Ld}/10}) \right] \quad (T_d \neq 0, T_{ev} = 0, T_n \neq 0)$$

$$\text{Lden} = 10 \log \left[\frac{1}{12+8+4} (12 \cdot 10^{\text{Ld}/10} + 4 \cdot 10^{\text{Le}/10} + 8 \cdot 10^{\text{Ln}/10}) \right] \quad (T_d \neq 0, T_{ev} \neq 0, T_n \neq 0)$$

LEPd result

The **LEPd** result (Exposure level related to 8-hours working day is calculated on the base of the **LEQ** from the formula:

$$\text{LEPd} = \text{LEQ} + 10 \cdot \log \frac{T_e}{T_{8h}}$$

Ltm3 and Ltm5 results

The Ltm3 and Ltm5 results (Takt-Maximal Levels) are calculated according to the German standard TA Larm.

OVL result

The **OVL** result (Overload) presents the percentage of the overloaded input signal, which occurred during the selected T_c - measurement time set in the **INTEGR. PERIOD** (*path: MENU / INPUT / MEASUREMENT SETUP / INTEGR. PERIOD*).

PEAK value

The **PEAK** value (Peak Sound Pressure or Peak Sound Level) depends on the weighting filter **W** (equal to **A**, **C** or **Z**) and is calculated for the given **T** from the formula:

$$\text{PEAK} = 20 \log \left(\max_T \left| \frac{a_w(t)}{p_0} \right| \right)$$

In the case of the **PEAK** value saved as the main result $T = T_c$. When the **PEAK** value is saved in the files of the logger (time-history) - $T = T_b$.

MAX result

The **MAX** result means the maximal value on the detector output for the integration period. The **MAX** result for the period of 1 second is equal to the value of the **SPL** function. The **MAX** result is calculated according to the formula:

$$\text{MAX} = 20 \log \left(\max_T \frac{p_w(t)}{p_0} \right)$$

In the case of the **MAX** value saved as the main result $T = T_c$. When the **MAX** value is saved in the files of the logger (time-history) - $T = T_b$.

MIN result

The **MIN** result is calculated according to the formula:

$$\text{MIN} = 20 \log \left(\min_T \frac{p_w(t)}{p_0} \right)$$

In the case of the **MIN** value saved as the main result $T = T_c$. When the **MIN** value is saved in the files of the logger (time-history) - $T = T_b$.

Lnn statistical Levels

The noise level $L(t)$ is the continuous random variable. The probability that the temporary noise level $L(t)$ belongs to the interval $\langle L_k, L_k + \Delta L \rangle$ is called the class density and it can be expressed by the equation:

$$P_k [L_k \leq L(t) \leq L_k + \Delta L] = \sum_{i=1}^n \Delta t_i / P$$

where:

Δt_i - time intervals, in which the noise level $L(t) \in \langle L_k, L_k + \Delta L \rangle$ occurs,

ΔL - so-called class interval or distribution class of the series,

P - total observation period.

In the case when the class interval approaches infinity, the probability of $L(t)$ tends to the probability of L_k . In practice, ΔL value is strictly determined and it depends mainly on the dynamics of the measurements performed in the instrument. In the SV 102 instrument, there are 120 classes and the width of each class is equal to 1 dB.

The histogram is the set of the class density values calculated for all classes. In SV 102 instrument the histogram is saved in the result files if the **SAVE STATISTICS** (path: MENU / FILE / SAVE OPTIONS / SAVE STATISTICS) is activated (cf. the detailed description of the relevant table in App. B).

The statistical distribution function, which determines the probability (expressed in %) of the noise occurrence on the level equal or less than $L_k + \Delta L$ is given by the formulae:

$$P[L(t) \leq L_j] = \sum_{k=1}^j P_k(L)$$

The cumulative density function, expressed by the equation:

$$P[L(t) > L_j] = 1 - P[L(t) \leq L_j]$$

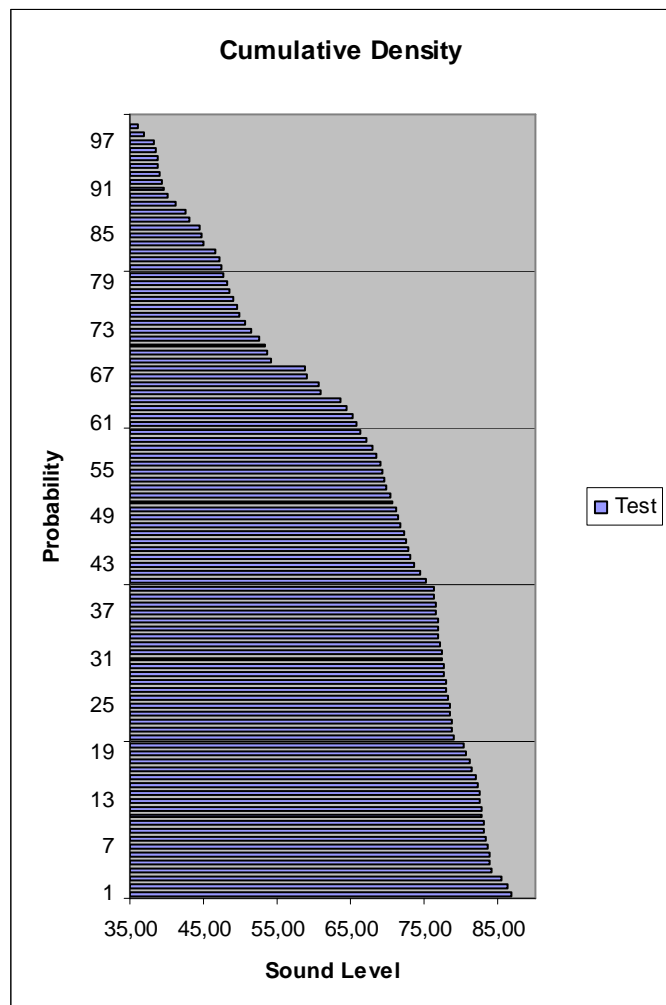
is directly used to determine so-called statistical levels **Lnn** or position parameters of the distribution.

The **Lnn** is the certain boundary level surpassed by the temporary noise level values in not more than **nn%** of the observation period.

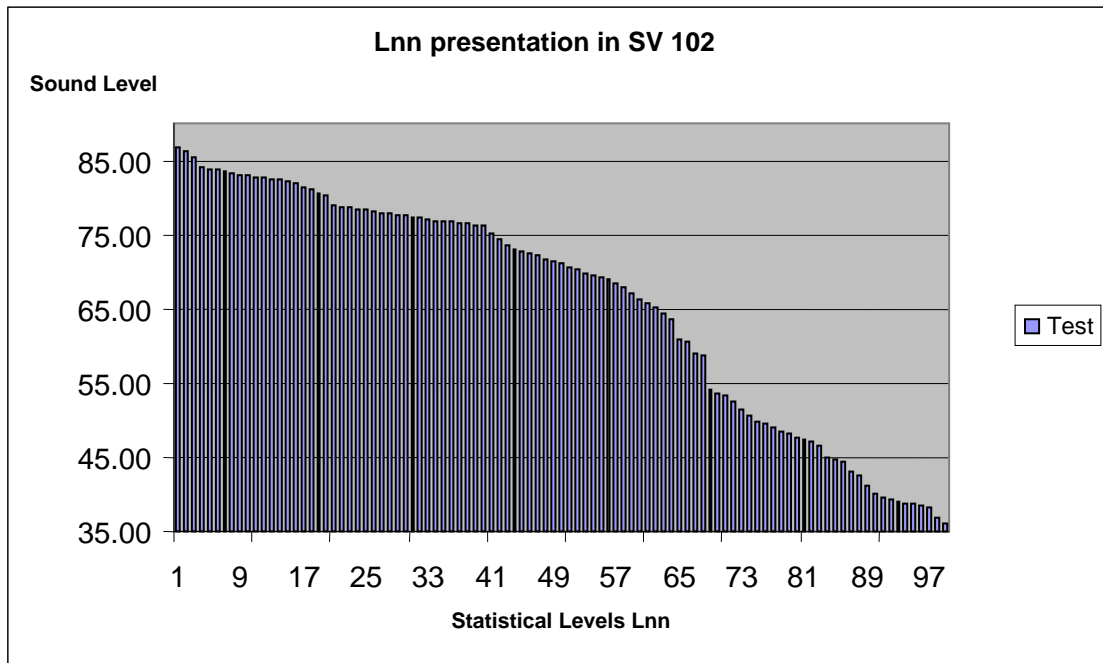
Example: Let us assume that **L35** is equal to 76.8 dB. It means that during the measurements the noise level 76.8 dB was exceeded in not more than 35% of the observation period.

The cumulative density function for the exemplary data is presented in Figure on the right side. In order to determine the **Lnn** level one has to draw the horizontal cursor and find out the crossing point between the cumulative density function and the cursor. In the SV 102 instrument the user can determine 99 statistical levels - from **L01** to **L99** (1% step of observation period).

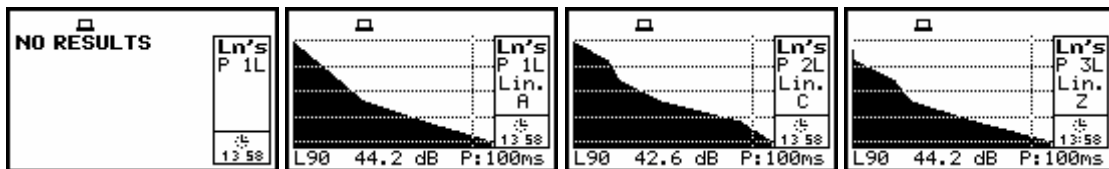
The display in the SV 102 instrument has only 64 pixels on the vertical axis and 128 on the horizontal one. It is obvious that



the change of the axes is more suitable for the presentation of 99 statistical levels. In this case, the user has to draw the vertical cursor and the value on it gives the required statistical level (the value of the noise level, which happened during the performed measurements in not more than selected percentage of the observation period).

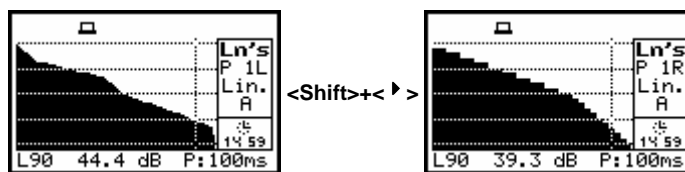


In the statistical level presentation mode the **Lnn** values, selected by the cursor, are displayed in the bottom line together with its value and units (dB). The P value indicating the observation period equal to 100 ms (it means that the statistical results are updated every 100 ms) is placed at the end of the bottom line. The profile's number the statistics are taken from, the RMS detector (**Lin.**, or **Exp.**: **Fast**, **Slow** or **Imp.**), the filter's name (**A**, **C** or **Z**) and the current time are displayed on the right side of the display.

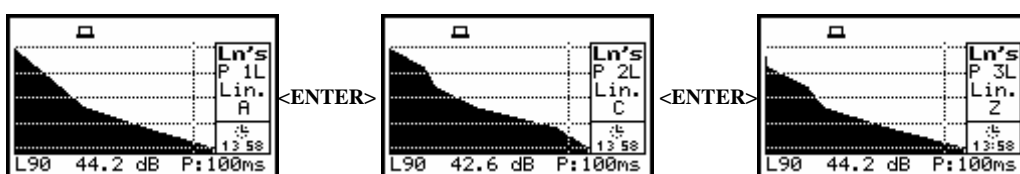


Results shown in the first presentation mode of statistical levels

The selection of the Lnn to be displayed is done by pressing the <<<>, <>>> push-buttons. The change of the channel is made with <Shift> and <>>> push-buttons. The selection of the profile is done by pressing <Shift> and <ENTER>.



Statistics presentation mode, change of the channel

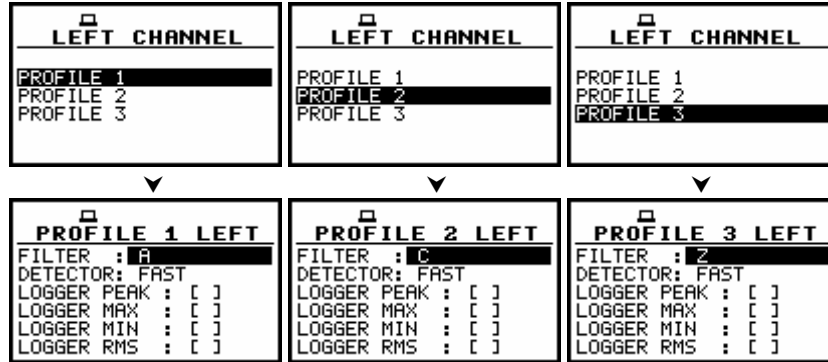


Statistics presentation mode, change of the profile

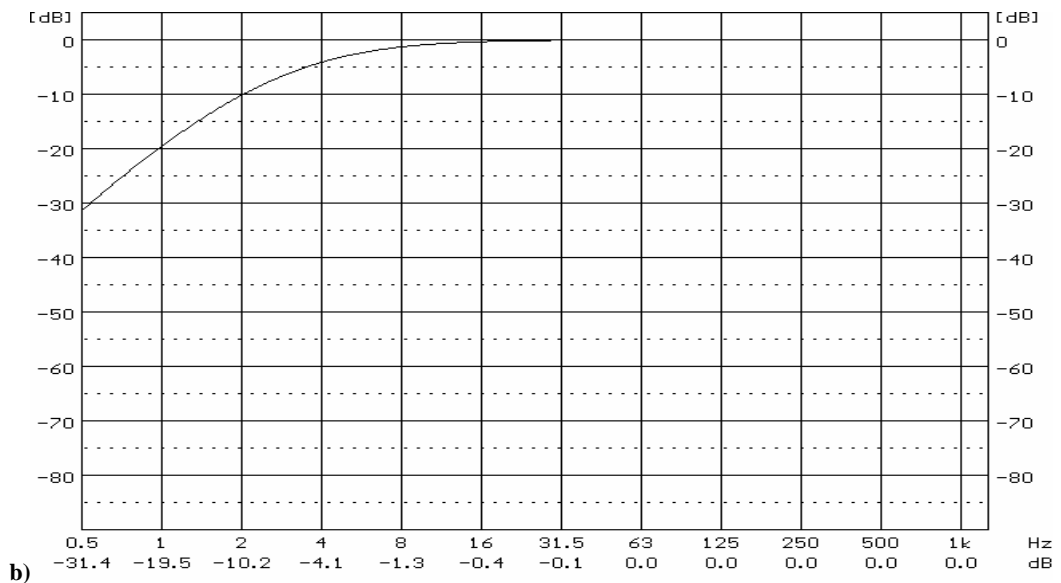
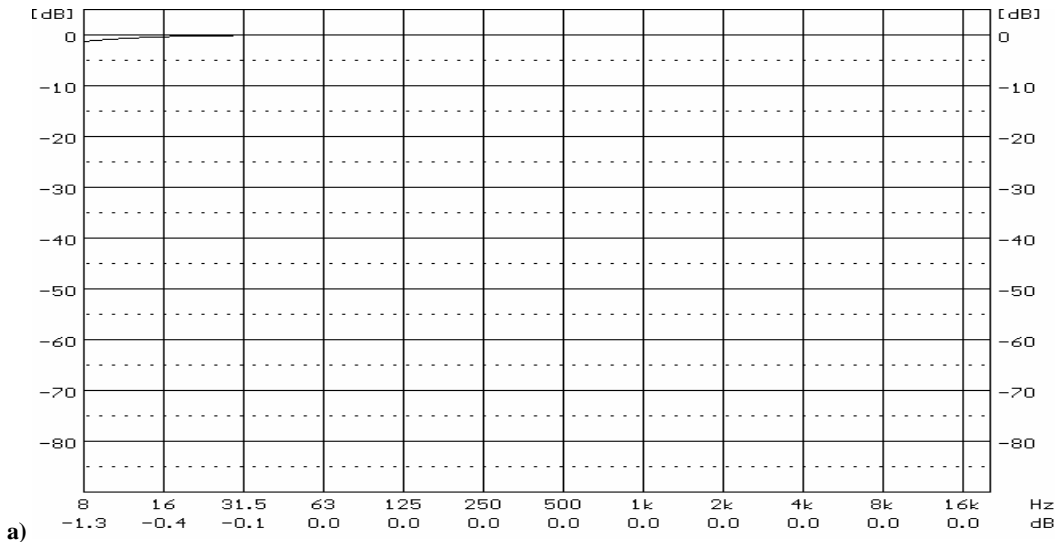
D.2. Frequency characteristics of the implemented digital filters

D.2.1. Weighting filters in the SLM mode

The weighting filters, which are available in the device (**A**, **C** and **Z**) are selected in the **PROFILE (x)** windows (path: MENU / INPUT /LEFT(RIGHT) CHANNEL/ PROFILE (x)).

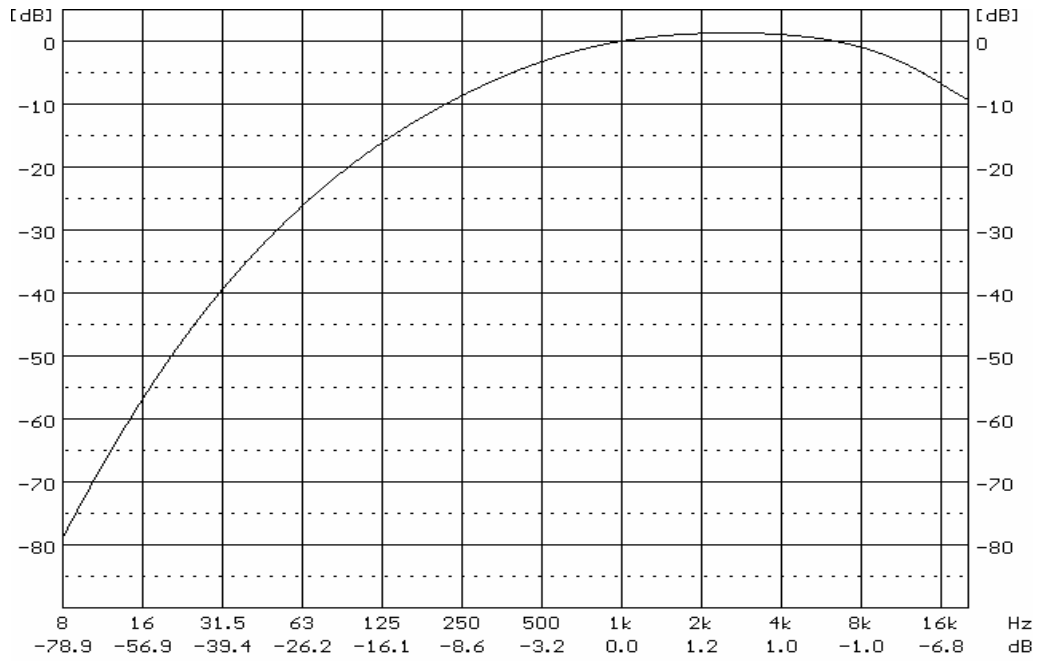


INPUT and PROFILE (x) windows; weighting filter selection



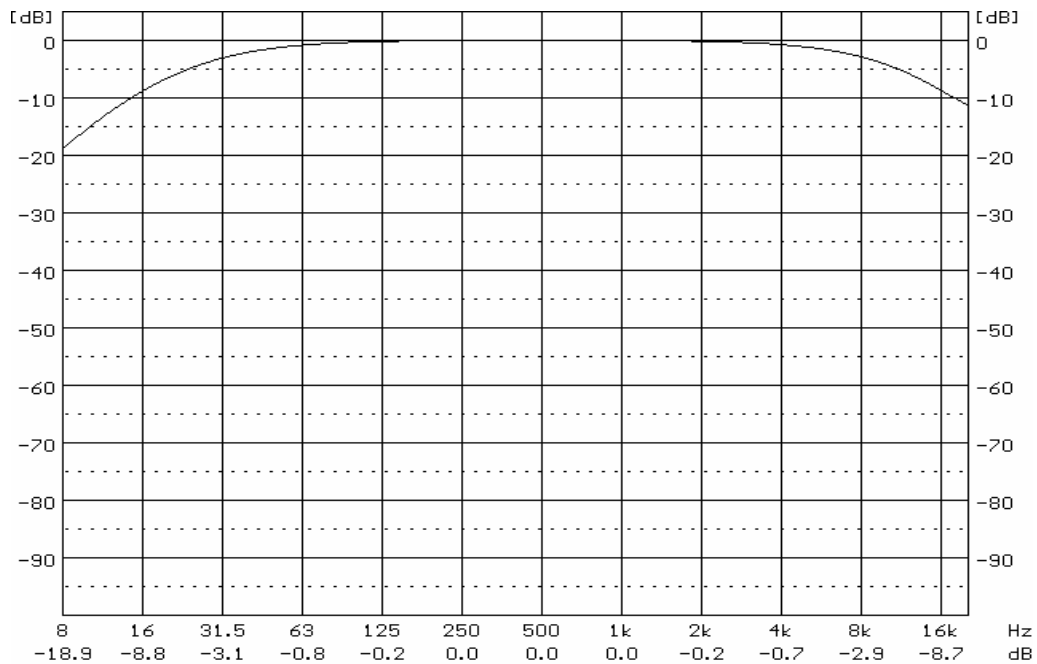
Full (a) and low band (b) frequency characteristics of Z filter implemented in the instrument

A type 1 according to the IEC 651 standard.



Frequency characteristics of A filter implemented in the instrument

C type 1 according to the IEC 651 standard.



Frequency characteristics of C filter implemented in the instrument