DEWETRON

OXYGEN Sound Level Determination

TECHNICAL REFERENCE MANUAL

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1 PREFACE

OXYGEN's sound level option can be used for determining the time dependent sound pressure level according to IEC 61672 and IEC 651. The following features are available:

- Frequency weighting: A-, B-, C-, D- or Z weighting
- Time weighting: fast (125 ms), slow (1000 ms) or impulse (35 ms / 1500 ms)
- Reference level p_0 available for airborne sound (20 µPa) or water (1 µPa)
- Energy equivalent sound pressure level $L(A)_{eq}$
- Time dependent sound pressure level
- Minimum and maximum occurring sound pressure level
- Statistical (percentile) sound pressure Levels
- Above mentioned values can be determined for the entire measurement or block-wise per definable time interval
- Raw frequency weighted sound pressure in original unit [Pa]
- Noise exposure level $L(A)_{Ex,8h}$ and Noise Dose D

Benefits:

- Statistical sound pressure level analysis
- (Long term) sound monitoring
- Sensor sensitivity can be entered manually or determined with calibrator
- Sound pressure level determination for airborne sound and water
- Interval-wise logged sound pressure levels

1.1 INSTALLATION AND LICENSING

The sound level option is automatically installed with every OXYGEN R5.2 (June 2020) and above. Once installed, the option needs to be licensed (if not done by DEWETRON factory already) and activated.

The license can be updated under the System Information tab (see Figure 1-1). This requires a *.lic-file provided by DEWETRON. A license update requires a restart of OXYGEN.

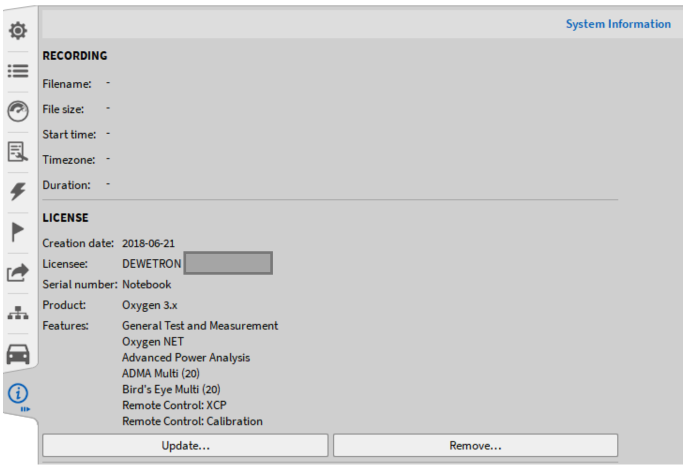

Figure 1-1: Updating the OXYGEN-license

2 SOFTWARE CONFIGURATION

This manual is only referring to the sound level option. For general software operation instructions, please refer to the latest version of the OXYGEN technical reference manual available on the CCC-portal (https://ccc.dewetron.com/).

2.1 CHANNEL SETUP

- Connect the microphones to the hardware and open the channel setup (see ① in Figure 2-1).
- Select the proper amplifier options for your sensor (typically IEPE mode) and set up the correct excitation current (see ② and ③ in Figure 2-1).
- To enter the sensitivity of the sensor, select *Sensitivity*, enter the correct unit [Pa] and enter the correct sensitivity (see ④ in Figure 2-1).

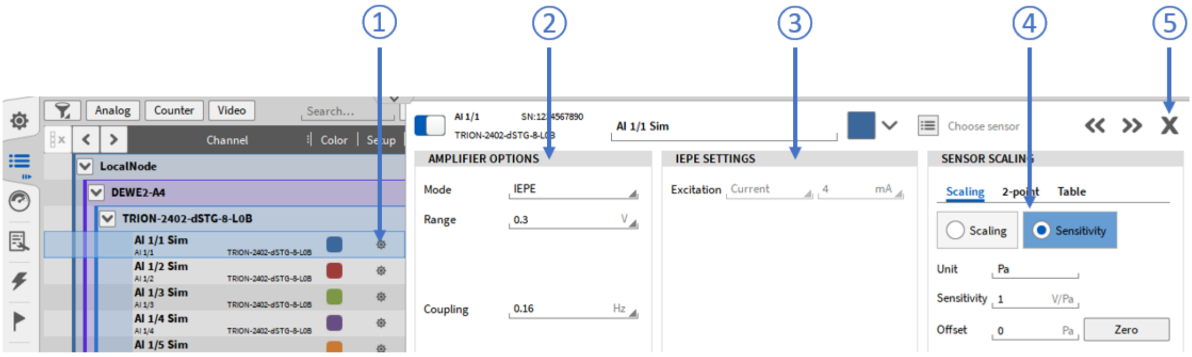

Figure 2-1: Channel Setup

2.2 CALIBRATION

- If a calibrator is used for sensitivity determination, go to the *2-point* sensor scaling tab and enter the unit [Pa] (see ① in Figure 2-2).
- Let the settings 0 V and 0 Pa untouched (see ② in Figure 2-2). This means that 0 V measurement signal equals 0 Pa.
- Enter the reference RMS-sound pressure of the calibrator in ③ in Figure 2-2. This is 1 Pa_{RMS} for a 94 dB calibrator and 10 Pa_{RMS} for a 114 dB calibrator.
- When the calibrator signal is stable, press the *AC RMS* button (④ in Figure 2-2). The AC RMS level of the calibrator will be averaged for the last 1 second.

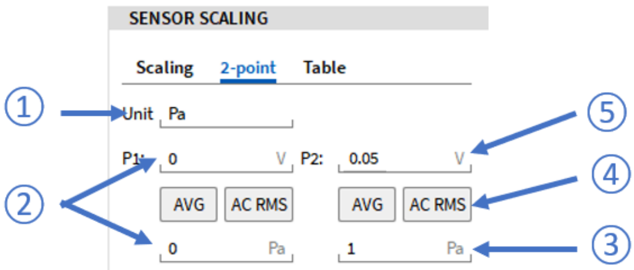

Figure 2-2: Sensitivity determination using a calibrator

- The sensitivity will be calculated automatically and copied into ⑤ in Figure 2-2.

2.3 CREATING A SOUND LEVEL DETERMINATION

- Close the Channel Setup by pressing the *X*-button (see ⑤ in Figure 2-1).
- Select the input channels for which a sound level shall be determined by selecting their check-boxes in the Channel List (see ① in Figure 2-3).
- Press the *+* button (see ② in Figure 2-3).
- Select the *Sound Level* section (see ③ in Figure 2-3), perform the required settings (see ④ in Figure 2-3) and select the desired output channels (see ⑤ in Figure 2-3).
  The settings are explained in detail in section 3.
- Press the *Add*-button (see ⑥ in Figure 2-3).

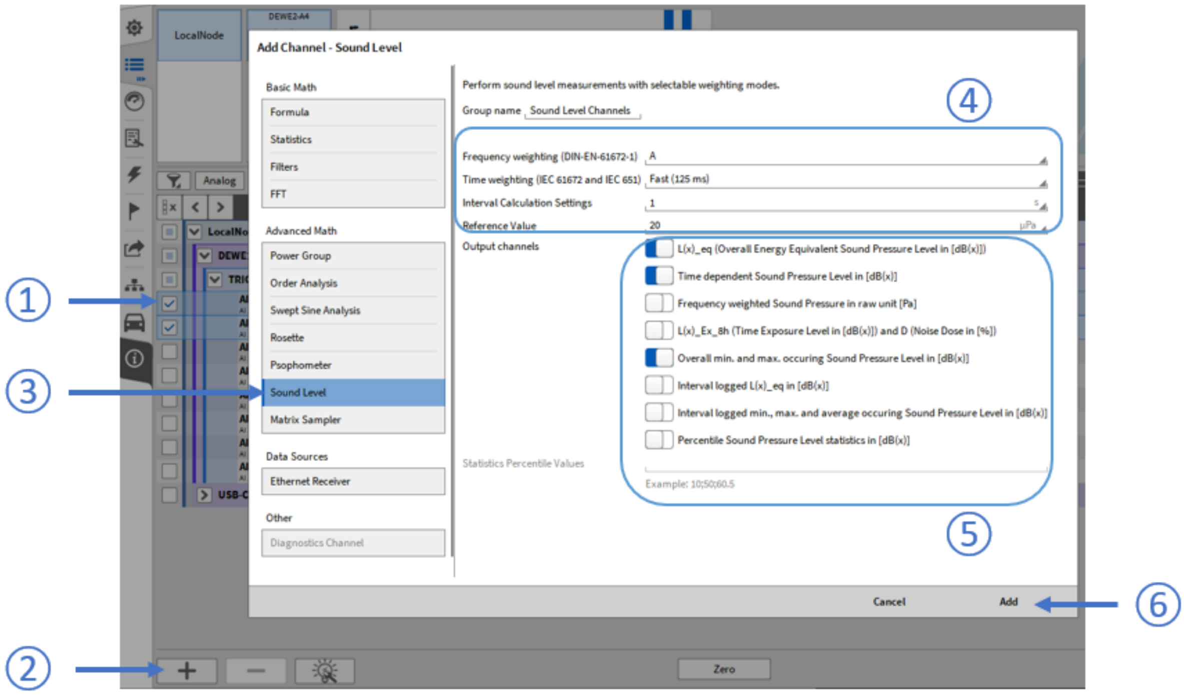

Figure 2-3: Creating a sound level determination

- A new sound level determination will be added to the Channel List. A separate section with output channels per input channel will be created and can be expanded by pressing the Arrow button (see ① in Figure 2-4).
- The settings can be edited by pressing the *Gear* button of the *Sound Level* group (see ② in Figure 2-4).
- The options, input channels and output channels can be edited in ③ in Figure 2-4.

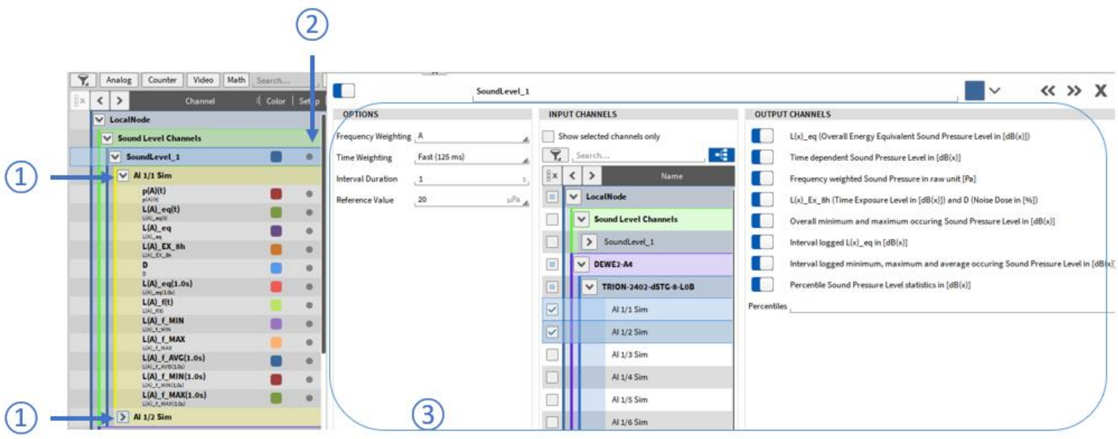

Figure 2-4: Sound level channels available in the Channel List and editing the settings

3 SOUND LEVEL SETTINGS

- Frequency:
  A-, B-, C-, D and Z-weighting according to IEC 61672 can be selected for the sound level determination.
  An introduction in the theory of frequency detection of the human ear can be found in section 5.1.

- Time weighting:
  Fast (125 ms), slow (1000 ms) and impulse (rising 35 ms / falling 1500 ms) can be selected for the sound level determination. Fast and slow time weighting are compliant with IEC 61672 and impulse weighting complies with IEC 651.
  A quick introduction into the theory of time weighted sound pressure levels can be found in section 5.2.

- It is possible to update certain output signals interval wise. The time interval can be selected from 0.1 s to 10 s.

- It is possible to select the reference sound pressure level p_0 for airborne sound which is 20 µPa or the reference sound pressure level p_0 for water which is 1 µPa.

4 OUTPUT SIGNALS

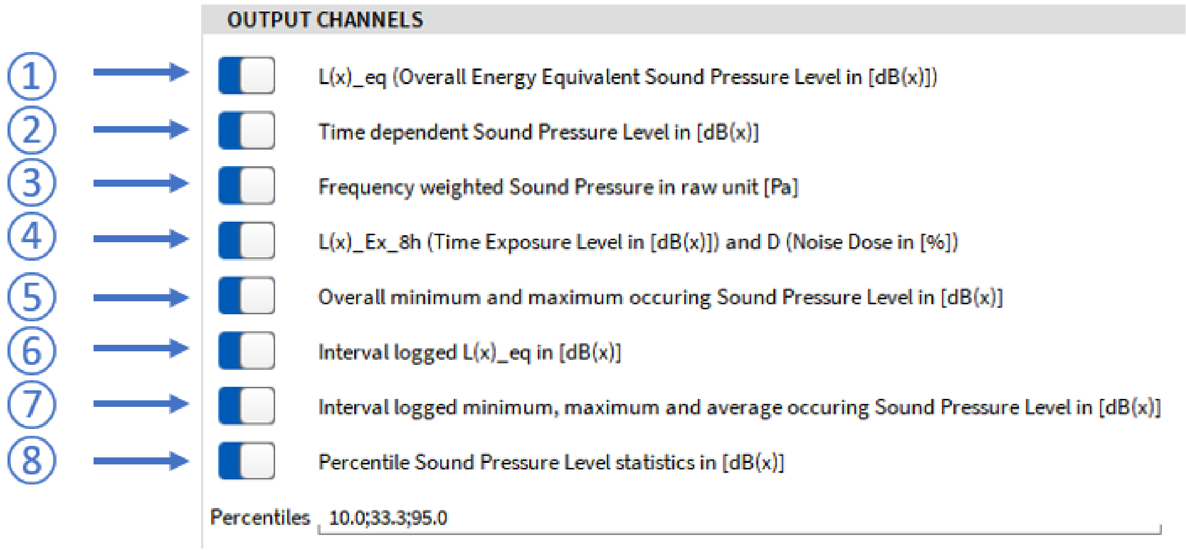

Figure 4-1: Available output signals - overview

- *L(x)_eq (Overall Energy Equivalent Sound Pressure Level in [dB(x)])* (see 1 in Figure 4-1)

  Outputs the energy equivalent sound pressure level $L(x)_{eq}$ for the entire measurement (see 1 in Figure 4-3).
  X denotes the selected frequency weighting (A, B, C, D, Z).
  The averaging is started at recording start and ends at recording end.

  Two output channels will be created:
  - *L(x)_eq* is a single value channel and contains only the $L(x)_{eq}$ for the entire measurement. The time dependent trend will be displayed during the measurement but won't be stored to the data file but only the last value.
  - *L(x)_eq(t)* contains the time dependent trend of the $L(x)_{eq}$. This information is also stored to the data file.

  Actually, the $L(x)_{eq}$ is only defined for A-weighted signals according to IEC 61672. But for the sake of completeness, this value is also determined if another frequency weighting is selected.

  The $L(A)_{eq}$ is determined according to the following formula:

$$L(A)_{eq}\ [dB(A)] = 10 * \log_{10}\left[\frac{1}{T}\sum_{i=1}^{T}\frac{p(x)^2}{p_0^2}\right]$$

p_0 … Reference sound pressure level, i.e. 20 µPa
T … Measurement time

- *Time dependent Sound Pressure Level in [dB(x)]* (see 2 in Figure 4-1)

  Outputs the time dependent frequency and time weighted sound pressure level $L(x)_\tau$ (see 2 in Figure 4-3).
  X denotes the selected frequency weighting (A, B, C, D, Z) and τ denotes the selected time weighting (fast, slow, impulse).

$$L(x)_\tau\ [dB(x)] = 10 * \log_{10}\left[\frac{p(x)^2}{p_0^2}\right]$$

P_0... Reference sound pressure level, i.e. 20 µPa

The calculation block diagram can be seen in Figure 4-2:

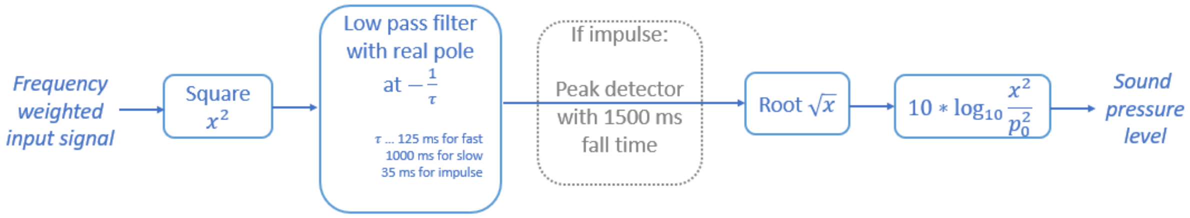

Figure 4-2: Time weighting of the frequency weighted in signal - block diagram

- *Frequency sound pressure in raw unit [Pa]* (see 3 in Figure 4-1)

  Outputs the frequency weighted raw signal *p(x)(t)* without time weighting in the linear (non-logarithmic) domain (see 3 in Figure 4-3).
  X denotes the selected frequency weighting (A, B, C, D, Z).

- *L(x)_Ex_8h (Time Exposure Level in [dB(x)]) and D (Noise Dose in [%])* (see 4 in Figure 4-1)

  Outputs the daily noise exposure level $L(x)_{Ex,8h}$ for and the equivalent noise dose D for a reference level of 85 dB (see 4 in Figure 4-3).
  X denotes the selected frequency weighting (A, B, C, D, Z).

  The daily noise exposure level is determined according to the following formula:

$$L(A)_{EX,8h}\ [dB(A)] = L(A)eq + 10 * \log_{10}\left[\frac{T}{T0}\right]$$

T ... Measurement time
T_0 ... Reference time 8h

  And the noise dose according to the following formula:

$$D\ [\%] = 10^{\frac{\frac{L(A)_{EX,8h} - L(A)_{EX,T0}}{Q}}{\log_{10} 2}} * 100$$

$L(A)_{Ex,T0}$ ... Noise exposure limit, 85 dB
Q... Halfening parameter, 3 dB

  Actually, the $L(x)_{Ex,8h}$ is only defined for A-weighted signals. But for the sake of completeness, this value is also determined if another frequency weighting is selected.

- *Overall minimum and maximum occurring Sound Pressure Level in [dB(x)]* (see 5 in Figure 4-1)

  Outputs the minimum $L(x)_{\tau,MIN}$ and maximum $L(x)_{\tau,MAX}$ occurring sound pressure level during the measurement as single value (see 5 in Figure 4-3).
  X denotes the selected frequency weighting (A, B, C, D, Z) and τ denotes the selected time weighting (fast, slow, impulse).

This means that the channels are continuously updated during the measurement, but no time trend is stored to the data file. The data file will contain only the overall minimum and maximum.

- *Interval logged L(x)_eq in [dB(x)]* (see ⑥ in Figure 4-1)

  Outputs the $L(x)_{eq}$ calculated for time intervals between 0.1 s and 10 s (see ⑥ in Figure 4-3). The time interval can be specified in the sound level options (see ③ in Figure 2-4).
  X denotes the selected frequency weighting (A, B, C, D, Z)

- *Interval logged minimum, maximum and average occurring Sound Pressure Level in [dB(x)]* (see ⑦ in Figure 4-1)

  Outputs the $L(x)_{\tau,MIN}$ and $L(x)_{\tau,MAX}$ and $L(x)_{\tau,AVG}$ calculated for time intervals between 0.1 s and 10 s (see ⑦ in Figure 4-3).
  The time interval can be specified in the sound level options (see ③ in Figure 2-4).
  X denotes the selected frequency weighting (A, B, C, D, Z) and *τ* denotes the selected time weighting (fast, slow, impulse)

  Remark: The difference between the interval logged $L(x)_{eq}$ and $L(x)_{\tau,AVG}$ is that the $L(x)_{\tau,AVG}$ is time averaged but the $L(x)_{eq}$ is not.

- *Percentile Sound Pressure Level statistics in [dB(x)]* (see ⑧ in Figure 4-1)

  Outputs the sound pressure level(s) that are exceeded for a certain percentage of the measurement time (see ⑧ in Figure 4-3).
  X denotes the selected frequency weighting (A, B, C, D, Z).
  The percentage time of the measurement time can be entered in *Percentiles*. Several percentiles can be specified with a *';'* as delimiter.

  The example in Figure 4-1 which specifies 10.0 %, 33.3 % and 95.0 % outputs the statistical sound pressure level which is exceeded in 10.0 % of the measurement time ($L(x)_{\tau\,10.0}$), in 33.3 % of the measurement time ($L(x)_{\tau\,33.3}$) and in 95.0 % of the measurement time ($L(x)_{\tau\,95.0}$).

  This option can be used for statistical sound pressure level analysis which is frequently used during long time sound monitoring and room acoustics. I.e. the $L(A)_{\tau\,95.0}$ is regarded as the background noise level of an empty room.

Figure 4-3: Sound level output channels in the Channel List

5 APPENDIX

5.1 FREQUENCY DETECTION OF THE HUMAN EAR

The human ear can detect sound pressure deviation in a frequency range from ~20 Hz to 20 kHz. The ability of hearing decreases with increasing age. The full spectrum from 20 Hz to 20 kHz can be recognized to an age of ~20. After that the frequency range decreases with ~2 kHz per 10 years. For sure, these values are only indicators and depend on the individual human.
It is important to know that the human ability of hearing is frequency dependent. Medium frequencies can be recognized better than high or low frequencies. The following Figure 5-1 shows the dependency of the recognized sound pressure in the dependency of the frequency:

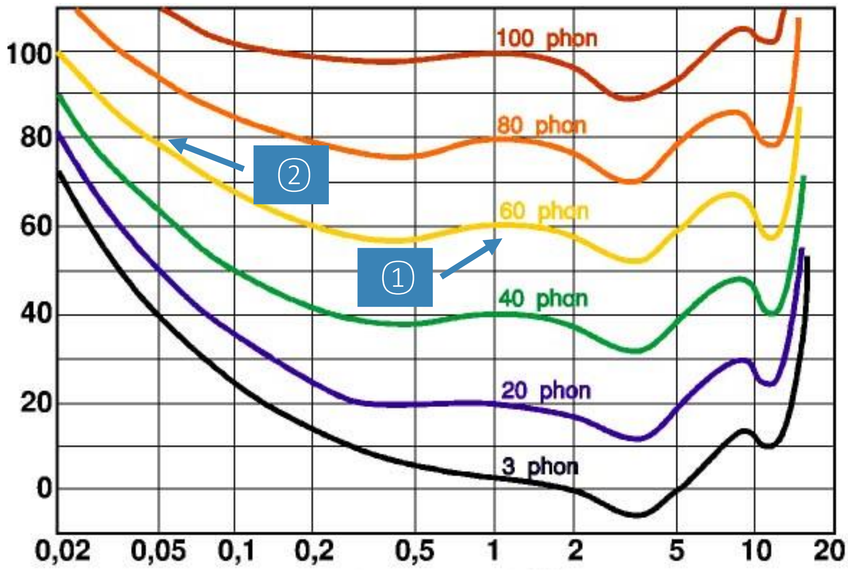

Figure 5-1: Phon curves[1]: X axis: Frequency [kHz], Y axis: Sound pressure level [dB]

To describe the frequency dependent sound pressure detection of the human ear, the so-called phon curves have been introduced by psycho acoustics. These curves show the sound pressures of equal loudness. Therefore, psycho acoustics introduced the unit *phon* for the loudness. 1 kHz is the reference frequency. This means that the loudness in phon always matches with the sound pressure in dB @1kHz. To give an example with the 60 phon curve, a sound pressure level of 60 dB @1 kHz is recognized as 60 phon loudness (see ① in Figure 5-1). But to recognize a loudness of 60 phon @50 Hz, a sound pressure level of ~80 dB is necessary (see ② in Figure 5-1).
60 dB or 80 dB may not sound that much but when the levels are recalculated from the non-linear logarithmic decibel-domain into the linear unit Pascal, 60 dB equal 200 mPa and 80 dB equal 20 mPa. Thus, this is a difference of the factor 10!

Note:

$$L_p[dB] = 20 * \log_{10} \frac{p[Pa]}{20\ \mu Pa} \rightarrow\ p[Pa] =\ 10^{\frac{L_p[dB]}{20}} * 20\ \mu Pa$$
$$\rightarrow\ 200\ mPa =\ 10^{\frac{60\ dB}{20}} * 20\ \mu Pa$$
$$\rightarrow\ 20\ mPa =\ 10^{\frac{80\ dB}{20}} * 20\ \mu Pa$$

[1]Source: https://de.wikipedia.org/wiki/Phon_(Einheit)

To respect these frequency dependent hearing characteristics during an acoustical sound pressure measurement, the frequency weighting curves are used (see Figure 5-2):

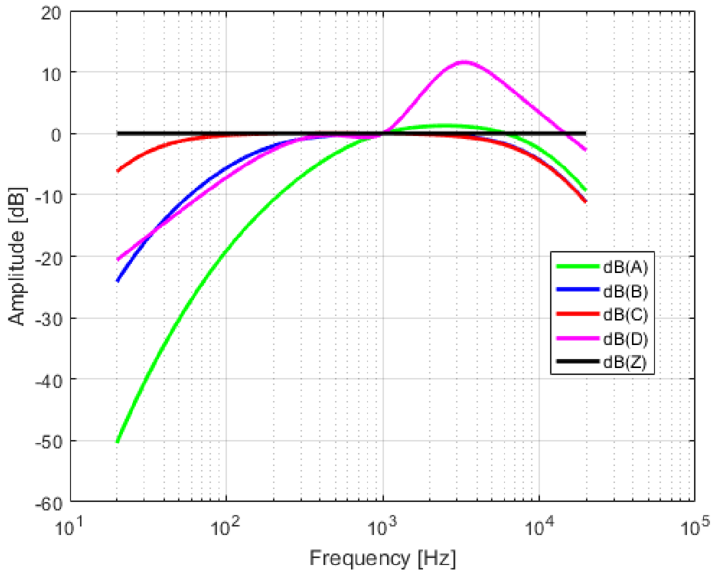

Figure 5-2: A-, B-, C- and D-Frequency weighting curves

Four different curves exist: A-weighting, B-weighting, C-weighting and D-weighting. A-weighting can theoretically be used for low sound pressure levels (30 phon), B-weighting for medium sound pressure levels (60 phon) and C-weighting for high sound pressure levels (90 phon). To weight very loud sound sources like aircraft noise, the D-weighting was introduced.
But in real-life only A-weighting is used with barely no exceptions, because B-weighting and C-weighting match hardly during subjective tests. The reason is that these curves were created based on tests for which pure (sine) notes were used. But pure notes never appear in real-life. Therefore, B-weighting is not used in real-life and C-weighting only rarely to evaluate peak-sound pressure levels. To mark which frequency weighting curve was used during a measurement, the letter A, B, C or D is added in brackets to the unit dB: dB(A), dB(B), dB(C) or dB(D). If none of these curves is used and the evaluation was linear, it is denoted by dB(Z) for *Zero*.

5.2 Time Weighting Characteristics

In time domain, the sound pressure level determination consists of a root mean square calculation on the one hand which makes the result proportional to the energy and on the other hand of an averaging over time which is the so-called time weighting. The time weighting shall point out different signal characteristics.
According to IEC 651 and EN 60651, 3 different time weighting options exist:

- Fast (risetime & falltime: 125 ms)
- Slow (risetime & falltime: 1000 ms)
- Impulse (risetime: 35 ms; falltime: 1500 ms)

From the mathematical point of view, the time weighting can be described by the following block diagram:

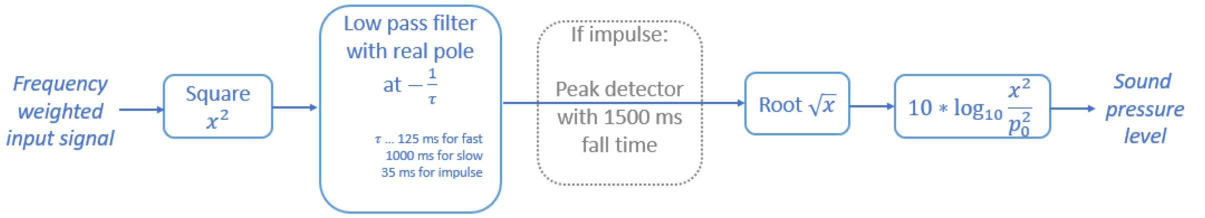

Figure 5-3: Block diagram for time weighting

In general, if the measurement value is changing quick, the shorter is the rise/falltime and it is harder to read off the value. In opposite, the longer the rise/falltime the slower the measurement value is changing and the easier it is to read it off.
For better understanding, think of an analog sound level meter from former times as it can be seen in Figure 5-4. The smaller the time constant, the quicker the needle is moving and the value can be read off harder.

Figure 5-4: Analog sound level meter

Here are some general recommendations for the usage of time constants:

- Fast (risetime & falltime: 125 ms):
  This time evaluation can be selected to take account of consecutive level changes. A reliable reading of the levels is not as easy with this time evaluation as with the slow time evaluation, since the levels change faster. Further processing to an effect-equivalent long-term assessment value is also more complex here.

- Slow (risetime & falltime: 1000 ms):
  Because of the high time constant of one second, the slow time evaluation has the advantage of smoothing large fluctuations in level, making it easier to read a level. At the same time, this time evaluation makes it easier to determine an effect-equivalent long-term evaluation value.

- Impulse (risetime: 35 ms; falltime: 1500 ms):
  If the short-term perception of the person is to be included in the assessment, the time assessment impulse can be selected. Due to the rapid rise time of 35 milliseconds, pulsed sound levels

are very well considered. Thanks to the long fall time of 1.5 seconds, it is again possible with this time constant to display these levels and to calculate a long-term level (it should be noted that noises that last less than a second are called impulses).

The individual time assessments are therefore coordinated with opposing characteristics. The time evaluation should be selected according to the criterion to which special attention should be paid to in the analysis.

Rising and falling signal edges and the effect for fast (blue), green (red) and impulse (red) weighted signals are compared in Figure 5-5.

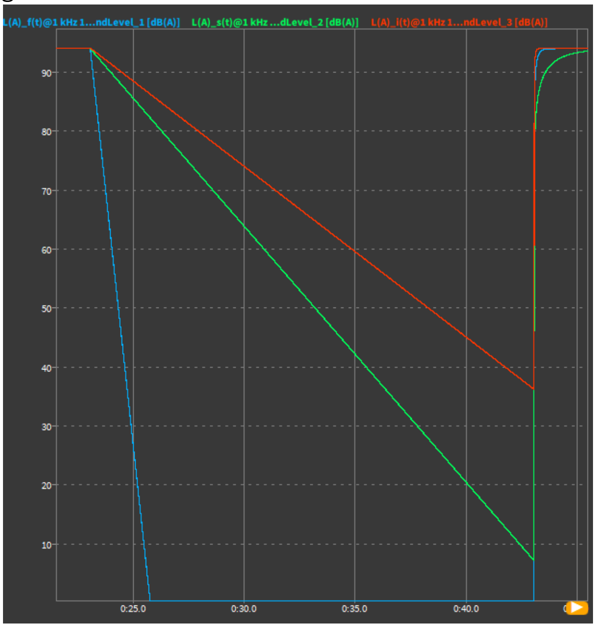

Figure 5-5: Comparison of the different time weightings

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