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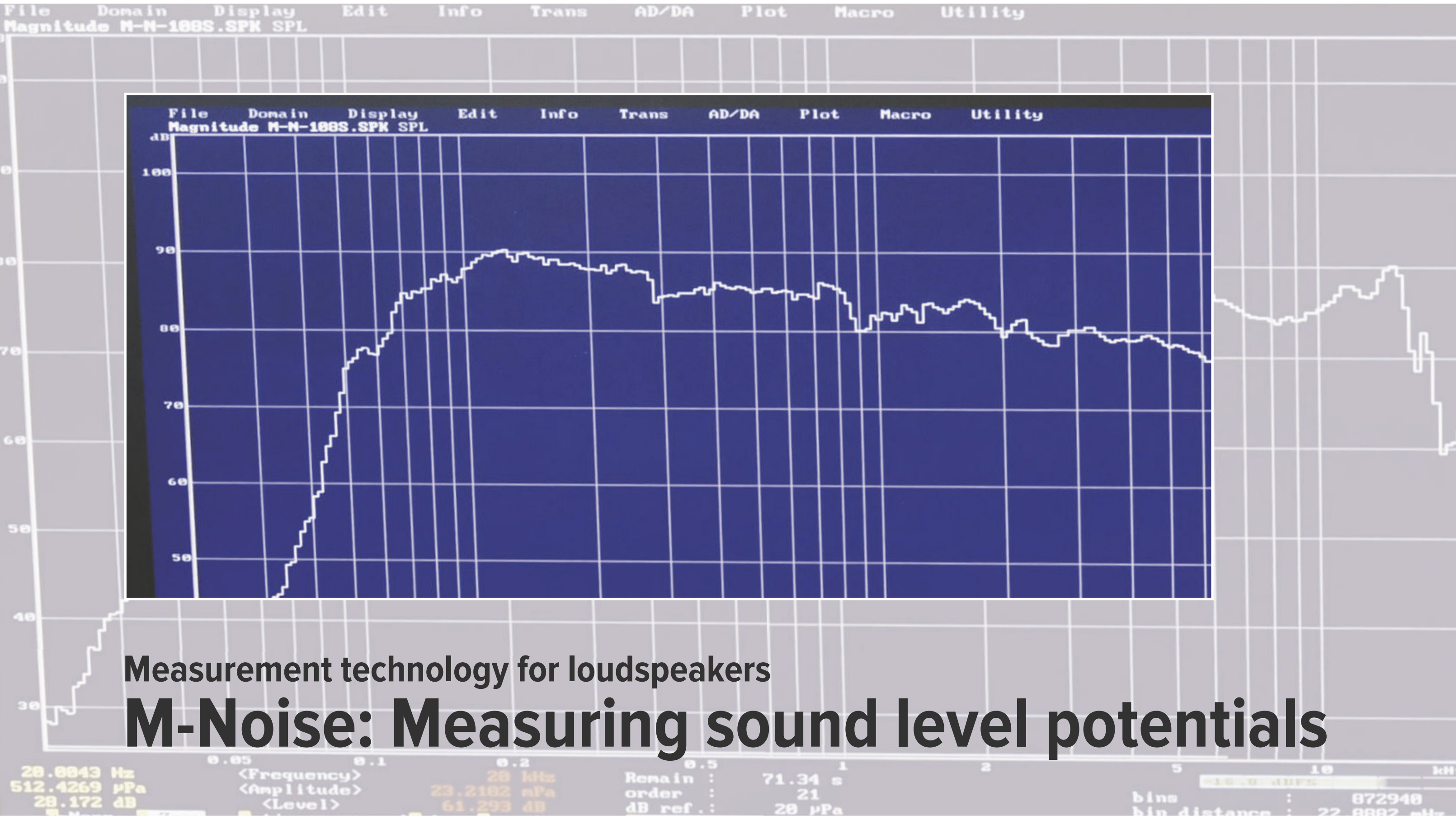

Measurement technology for loudspeakers

M-Noise: Measuring sound level potentials

How high is a loudspeaker's maximum level? This is a permanent topic in the world of sound reinforcement. As is the question of measurement – and how the values in some data sheets are achieved. As a suggestion for practical standardization, Meyer Sound has introduced its recommendation "M-Noise". What is new, where are the differences and benefits compared to previous measurements and how does one work with it?

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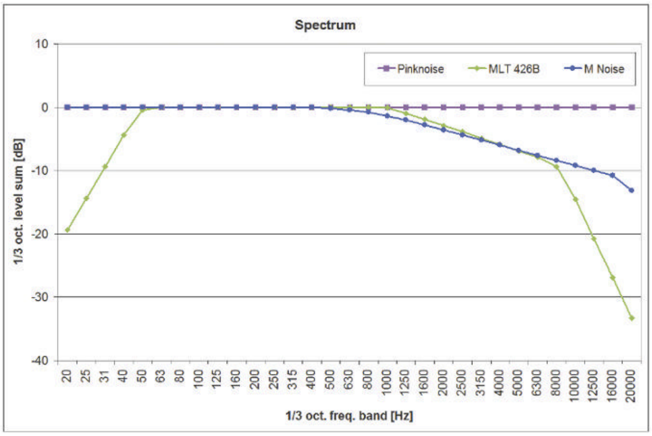
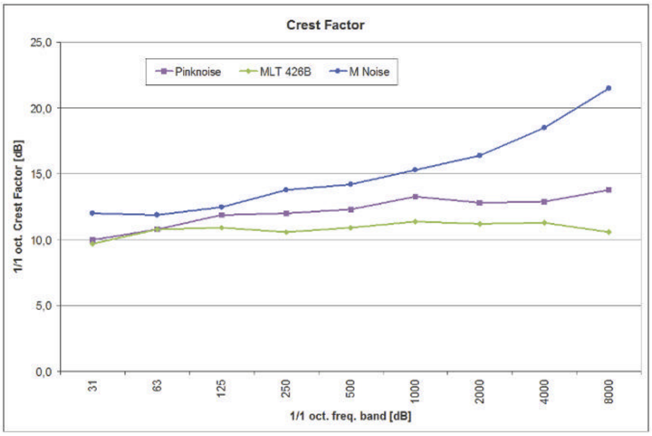


Third-octave band level *of a pink noise (pink), a multitone signal with EIA-426B spectrum (green) and an M-Noise (blue, Fig. 1)*



Crest factors *with third-octave bands of a pink noise (pink), a multitone signal with EIA-426B spectrum (green) and an M-Noise (blue, Fig. 2)*

The maximum level of most loudspeakers is specified in their brochures or data sheets. However, these usually lack concrete information regarding how this value was determined. And that is no small problem: A difference of 10 to 20 dB between a peak value calculated by the developer for the data sheet and the average level actually measured over a wide band can occur! As a user or planner, one asks: How can that be? And how can one get reliable values? Let's first clarify some terms and value definitions.

What does the maximum level mean?

On the acoustic side, one has the sound pressure, which is usually indicated as the energy equivalent continuous sound level L_{eq} (or equivalent sound level) over a defined period of time. Additionally – among many other values – one has the peak level L_{pk}. If one, for example, considers an uncompressed pink noise, the peak values in this signal are approximately four times greater than those of the average level. This ratio is also called the crest factor. The same applies to the electrical side. Here, the signal is defined by the effective value and the peak value of the voltage. For example, a sinusoidal signal's peak value is 1.414 times (3 dB) the effective value.

For many acoustic measurements of loudspeaker systems' maximum level, the average level Leq is used as a reference. It is calculated using the following formula:

$p_0 = 20\ \mu Pa$ as reference sound pressure for 0 dB

$T = t_2 - t_1$ as duration of time interval

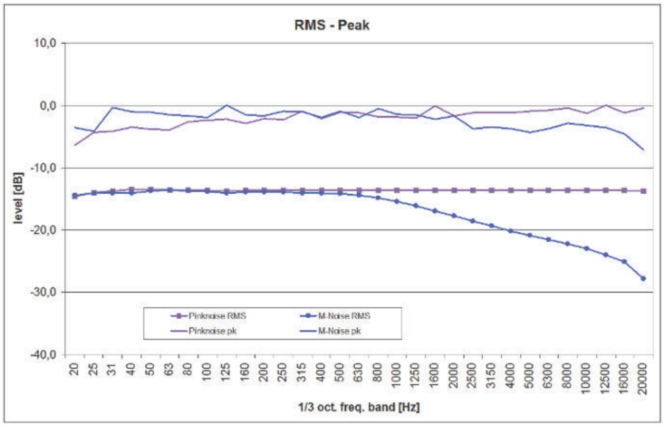
$$L_{eqT} = 20 \cdot \lg \frac{\sqrt{\frac{1}{T}\int_{t_1}^{t_2} p^2(t)\,dt}}{p_0}$$

Typical measured values for emission protection or for audience protection at concerts are defined as average levels for a certain period of time. For example, DIN 15905-5 "Measures to prevent the risk of hearing loss of the audience by high sound exposure of electroacoustic sound systems" specifies an average level of 99 dBA over 30 minutes as the limit value. As a second limit, a peak value L_{Cpeak} of 135 dB is specified, which must not be exceeded. Another good example is the achievable alarm level for a voice alarm system according to VDE 0833-4. With a speech substitute noise (such as the STIPA signal) as test signal, the average level is determined over a period of at least 16 seconds.

The IEC 60268-21 defines the average level for measuring the maximum level of loudspeakers with a time span of 1 s as "short term max SPL" or of one minute as "long term max SPL". In addition to the average level, the peak value L_{peak} can also be determined for the periods under consideration. As a measured value for the maximum level, however, this is associated with a higher uncertainty, as – depending on the frequency response – some dB deviations can quickly occur. However, this value is relevant when it comes to the undistorted transmission of highly dynamic music signals.

Signal spectrum and crest factor

Important test signal parameters are its spectral composition and the crest factor. The best-known signal for testing audio devices is the pink noise with a constant energy distribution across all frequency bands: When summed up over a third-octave or octave band, the level is always the same regardless of the frequency. The crest factor is approximately 4, corresponding to 12 dB.



Peak and RMS values *with third-octave bands for a pink noise (pink) and an M-Noise (blue). While the peak values are largely comparable and constant over frequency, the RMS value for the M-Noise decreases above 500 Hz (Fig. 3)*

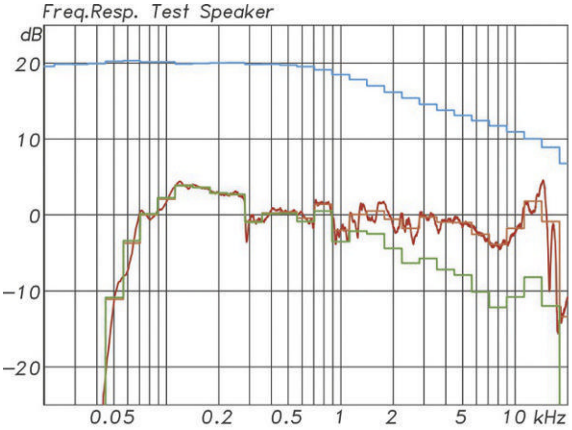
A pink noise's frequency spectrum can be limited with the help of appropriate high and low pass filters, for example for the measurement of woofers or tweeters. Alternatively, a typical programme signal spectrum as proposed in IEC 60268-1, CEA 2034 or EIA-426B can be simulated. If speech transmission is required, a medium speech spectrum according to IEC 60268-16 would be simulated.

By clipping the signal, the crest factor can also be influenced. The peak values are cut off until a desired crest factor is achieved. A value of 2 or 6 dB is typical here. The construction of such a test generator is quite simple even with analogue technology: Apart from the noise generator, one only needs a filter network for the desired frequency response and a simple diode circuit to clip the signal, followed by an adjustable catch-up amplifier.

With these signals, the level values can be determined and a possible destruction limit of the loudspeaker can also be examined. However, a statement regarding the actual audio quality or regarding distortion components in the signal is not possible! More on this later.

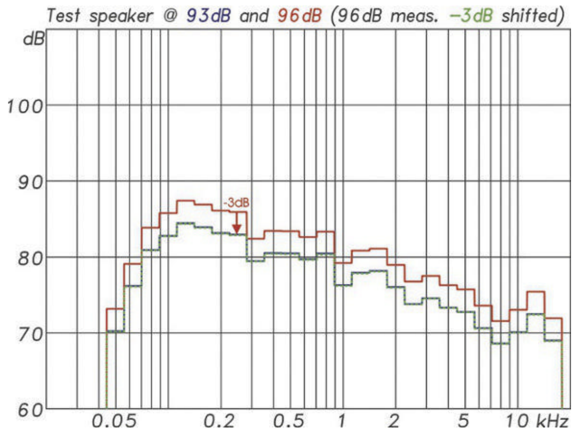
Idea: a more realistic test signal

Meyer Sound has now analysed music signals under these two aspects: the signal spectrum and the crest factor. In addition to the spectral composition, the crest factor was also determined. The crest factor, however, was not only analysed in a broadband way, as is usually done, but also as a function of the frequency band. It was found that the crest factor increases in the higher frequency bands (which is hardly surprising, especially for percussive music). As a logical consequence, Meyer Sound has now synthesised a noise signal that shows comparable behaviour to the analysed music signals. The result is M-Noise.

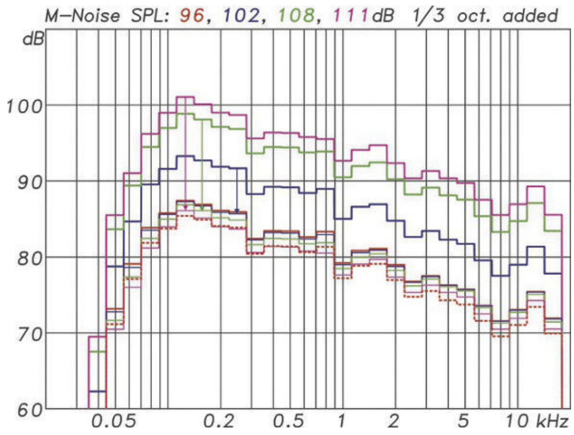


A test loudspeaker's *frequency response. Normal free-field measurement unsmoothed (red) and the resulting free-field measurement averaged in third-octave bands (orange). Above in light blue, the M-Noise signal's frequency spectrum in third-octave bands. In green, the M-Noise's spectrum after transmission via the test loudspeaker (Fig. 4)*

Fig. 1 shows the spectral composition of M-Noise compared to pink noise and EIA-426B spectrum. Two things stand out here: Above 8 kHz, M-Noise contains considerably more signal components compared to the EIA-426B spectrum. The reason for this could be the increase of the crest factor for the higher frequency bands. Even more significant, however, are the differences regarding the lower frequencies: M-Noise shows no level drop even at 20 Hz. For normal music signals, this is not the case – as the comparison with the EIA-426B spectrum shows. Below 40 Hz, music hardly has any signal components left, apart from special organ recordings or electronic music from the likes of "Kraftwerk". But since Meyer Sound also has a strong presence in the cinema business, it is obvious that film sound was the focus of attention here. If one is familiar with current blockbusters, the intention becomes clear. 20 Hz are needed for a real "disaster" feeling – with a really loud volume. Meyer Sound confirms this on request: The M-Noise test signal's bandwidth is in accordance with the SMPTE 2095-1 standard, as specified in the wave file's metadata comment section. For possible tests with M-Noise, one should therefore make sure in advance that the loudspeaker is equipped with a high-pass filter in the signal path, which then allows suitable tuning. By the way, those who want to carry out their own tests, signal and documentation are available
online: https://m-noise.org



Measurement using M-Noise *with 93 dB (blue) average level (Leq). The red curve was then measured with a 3 dB higher level. If one then shifts the second measurement down again by 3 dB (green), the blue and green curves are congruent. The loudspeaker therefore still operates largely in the linear frequency range (Fig. 5)*

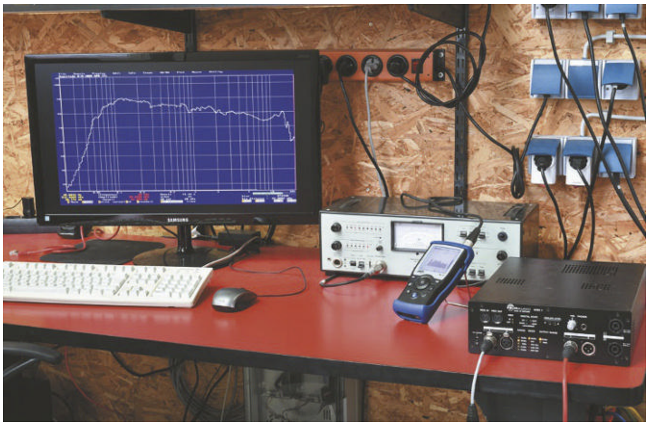


M-Noise measurements *now with higher levels compared to the 96 dB measurement (red curve) in Fig. 5. For the blue curve, the level was increased by 6 dB, for the green curve by 12 dB and for the magenta curve by 15 dB. If one then shifts the curves measured in this way down again by the respective value of the level increase, the power compression becomes visible. At +15 dB, the deviations due to power compression are already greater than 2 dB in some third-octave bands (Fig. 6)*

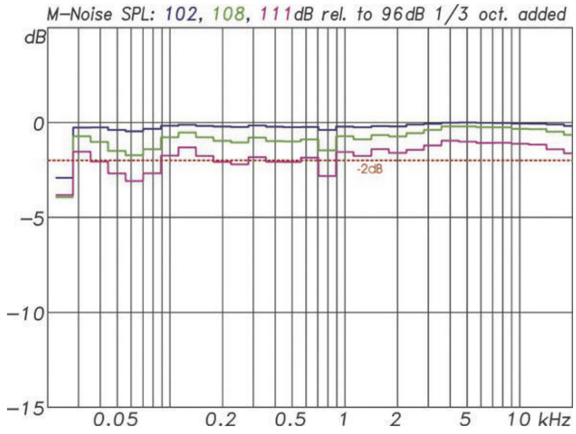
The analysis becomes really interesting, when it comes to the frequency-dependent crest factor in Fig. 2. While the values for the pink noise and also for a multitone signal with EIA-426B spectrum remain largely constant or rise only slightly towards the treble, the curve for M-Noise is quite steep. Some of the music signals we analysed on a trial basis showed a similar behaviour – highlighting the motivation of Meyer Sound's technicians regarding M-Noise synthesis. Our curves differ slightly from those in Meyer Sound's M-Noise documentation, which may be due to different analysis methods. However, the basic result is clear.
The connection is also clear in Fig. 3, where the RMS values' and the peak values' frequency-dependent course for the third-octave bands from 20 Hz to 20 kHz is shown for a pink noise and for M-Noise. The RMS values show the already familiar curve from Fig. 1. The peak value curves, however, are more or less level for both signals, more or less independent of frequency. The difference between the peak curve and the RMS curve corresponds to the crest factor.

Measurements with M-Noise

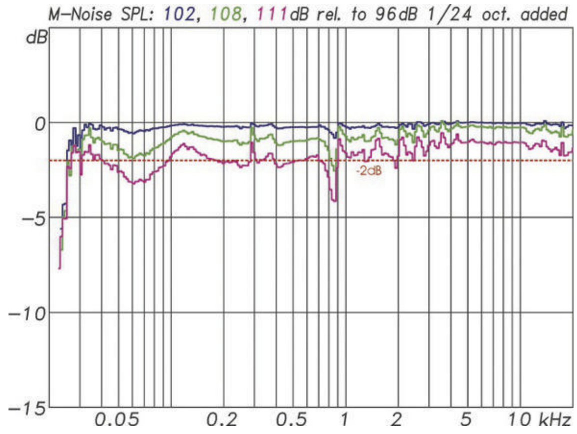
How Meyer Sound came up with M-Noise as a test signal has now been clarified. Now, how can a measurement be carried out that not only aims at a loudspeaker's destruction limit but also allows a statement to be made regarding the audio quality? Direct measurement of distortion is not possible with a noise signal, as distortion components and excitation signal cannot be separated. In 2008, Pat Brown already had an idea for this, which – in cooperation with AFMG – led to a small two-page paper entitled "Guide to Loudspeaker Power Testing". It suggested performing a frequency response measurement in the linear small signal range for the loudspeaker with the respective test signal. For this purpose, Pat Brown suggests a "music-like" noise as a test signal. This measurement is then defined as the reference curve. This is followed by the actual measurement, in which the level is increased step by step. If this level increase is then subtracted from the respective measurement, time and again, the ref-



Measurement work station *with PC software front end, NTI XL2, B&K-Preamp 2610 and computer screen with an M-Noise measurement result*



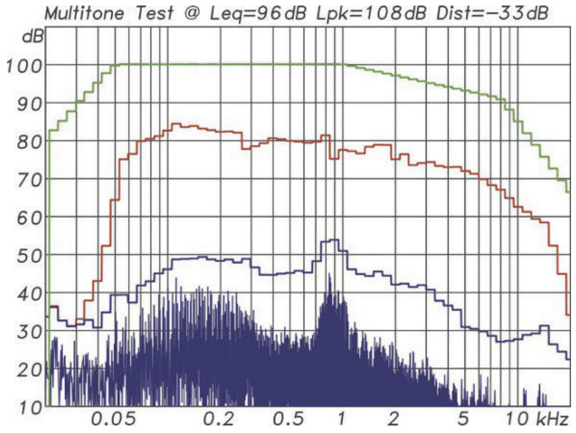
Relative representation *of the measurements from Fig. 6 in third-octave bands. The curves show the deviation from the 96 dB's calculated curve with level increases of 6 dB (blue), 12 dB (green) and 15 dB (magenta, Fig. 7)*



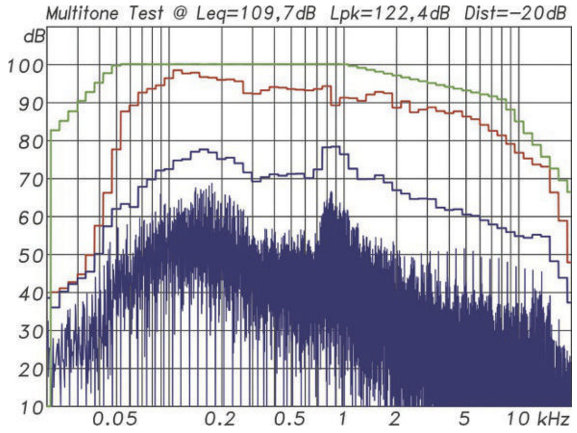
Relative representation *of the measurements from Fig. 6, now in 1/24 octave bands (Fig. 8)*

erence curve would have to be exactly the same for an ideal loudspeaker. In reality, however, the curve begins to deviate from the reference as the level increases: The frequency-dependent power compression or even possible protective circuits or limiters in the loudspeaker cause the curve to deviate from the reference to a greater or lesser extent. Now, there is only one criterion left to determine: which deviations are maximum permissible. At the time, Pat Brown proposed 3 dB as the maximum level loss for the average level. At Meyer Sound, it is now 2 dB. Pat Brown defined third-octave bands for the frequency resolution. For M-Noise evaluation, unfortunately, no concrete information is available. From the example measurements, a higher resolution of the order of 1/24 octave can be inferred. How exactly one must now take the evaluation and whether a tiny dent, which falls below the -2 dB limit value, is already seen as a limit, or whether the consideration rather takes place over a further frequency range, remains open.

The procedure up to the reference measurement is shown in Fig. 4 and 5. Initially, Fig. 4 shows the test loudspeaker's M-Noise spectrum (blue) and the unsmoothed free field frequency response (red). If this is presented in third-octave bands, the result is a stepped orange curve. M-Noise spectrum is changed accordingly during transmission over the loudspeaker. However, the loudspeaker's frequency response is not the issue, so this aspect is left out. The next step would be to check whether the loudspeaker is in the linear working range in the entire relevant frequency range.



Multitone measurement *with 96 dB Leq and 108 dB Lpk, the distortion component is –33 dB (=2.2%, Fig. 9)*



Multitone measurement *with 110 dB Leq and 122 dB Lpk, the distortion component is –20 dB (=10%, Fig. 10)*

According to M-Noise instructions, increasing the level by 3 dB and then decreasing the measured curve by 3 dB can easily provide a check for this. This procedure is shown in Fig. 5. The curve must be congruent with the first measurement (where the level is still 3 dB lower). If this is the case, then it is ensured that the loudspeaker operates in the linear working range.

Power compression

In the next step, the level is increased step by step and the measured curve is lowered again by the corresponding value. The measuring system we used automatically masters this function and, if required, also carries out a direct comparison with the reference or tolerance curve. Starting with the first measurement at 96 dB averaging level, the level for Fig. 6 was first increased by 6 dB and then by 12 dB compared to the 96 dB measurement. For a third measurement, a further 3 dB were added. From a purely mathematical point of view, the level values should then be 102 dB, 108 dB and 111 dB. However, only 101.8 dB, 107.1 dB and 109.1 dB were measured. In the last measurement, there was therefore a loss of 1.9 dB in broadband due to power compression. The first third-octave bands already reached the limit value of more than 2 dB deviation from the reference curve, which means that – according to M-Noise measurement specification – the limit was reached. The last measurement with 109.1 dB L_{eq} averaging level achieved a peak value L_{pk} of 124.7 dB.

Input [dB]	SPL [dB]	SPL L_{eq} [dB]	SPL L_{pk} [dB]
0	96 (Ref)	96	112
+6	102 (Calc.)	101,8	117,8
+12	108 (Calc.)	107,1	123,3
+15	111 (Calc.)	109,1	124,7

Calculated and measured level values *with M-Noise for level increases of 6, 12 and 15 dB compared to the reference value of 96 dB. (Table 1)*

The curves in Fig. 6 become somewhat clearer if they are only shown as a relative deviation from the reference measurement. In Fig. 7, with this type of presentation, the deviations that grow with increasing level can be clearly seen. The small sample loudspeaker measured here obviously has its weaknesses below 100 Hz and also in the 800 Hz third-octave band.

Test set-up *for the M-Noise test in the measuring lab's anechoic chamber. In front: The ¼" B&K 4939 measurement microphone with impedance converter*

If one would like to know more, then one can change the measurement from the 1/3 octave smoothed representation to 1/24 octave – resulting in Fig. 8's high-resolution curves. As soon as M-Noise measurement signal has been selected and the settings have been made in the measurement programme, this type of evaluation quickly produces a meaningful result for the achievable peak and average levels. A certain advantage of this measurement method is also that, to some degree, it can also be carried out in a non-anechoic environment. However, the values can then no longer be compared exactly with those of other loudspeakers or measurements from other rooms, as the room's diffuse field component influences the achievable maximum level value.

If one were to perform this measurement with a pink noise or a filtered pink noise with a frequency constant crest factor, the results would be comparable with the achievable averaging levels. The peak levels achieved, however, are higher when measured with M-Noise, provided that the loudspeakers' tweeters and the associated amplifier are capable of transmitting the high crest factor in the upper frequency bands without losses.

For this purpose, let us assume that the tweeter has a continuous thermal load capacity of 25 W at 8 Ω corresponding to 14,1 V_{rms}. In this case, a signal with 12 dB crest factor would require a maximum voltage of 56,6 V_{pk} and a signal with 18 dB crest factor of 113,1 V_{pk}. For the tweeter, the latter particularly calls for amplifiers, which can deliver high voltage and also high currents for a short time. With active loudspeakers, this is quite easy to achieve by feeding two powerful power amplifiers for high output voltages from a common power supply. All one needs to do is design the power supply unit to match the woofer at medium power output. The tweeter with comparatively low average power consumption places only a negligible load on the power supply unit. Nevertheless, the amp can supply the tweeter with the necessary voltage and current for short signal peaks.

If all technical requirements are met, then peak levels are measured with an M-Noise signal that are up to 6 dB above the values measured with a pink noise. The 6 dB correspond on average to M-Noise signal's higher crest factor in the upper frequency bands. Meyer Sound's Chief Loudspeaker designer Pablo Espinosa notes that this exactly matches his experience: Namely to achieve a peak level that is up to 6 dB higher by using real music signals in comparison to a measurement with pink noise. A measurement with M-Noise could therefore better represent the peak level performance of loudspeakers with correspondingly powerful amplifiers and tweeters. This is also the difference to Pat Brown's initially described measurement method, where the focus is not on the acoustic peak levels, but determining the maximum input voltage up to which a power compression of at most 3 dB occurs. The voltage value determined in this way can then be used as the maximum input voltage in an EASE-GLL simulation file.

Distortions

Stochastic noise signals are generally unsuitable for determining signal problems in the form of harmonic distortions (THD) or intermodulation distortions (IMD). If one wants to make a statement regarding these, one can use sinus bursts for THD measurements or – if one would wants to analyse both THDs and IMDs – also multitone signals. In the example shown here, the basis of the multitone signal consists of 60 sinusoidal signals with random phase, whose spectral weighting can be set at will (the number 60 is not necessarily fixed). For the following measurements in Figs. 9 and 10, the weighting of an average music signal according to EIA-426B (green curve) was selected. The crest factor of the measurement signal synthesised in this way is 4 (corresponding to 12 dB) and, as shown in Fig. 2, is largely independent of the frequency. For the distortion value derived from this type of measurement, all spectral lines that are not present in the excitation signal, i.e. which have been added as harmonic distortions or intermodulation distortions, are added together.

It is important to generate the excitation signal's frequencies in such a way that they do not coincide with the harmonic distortion components, as otherwise they could no longer be evaluated. With this type of measurement too, the level is increased until the proportion of total distortions (TD) reaches a certain limit value, for example 10%.

The multitone measurement from Fig. 9 was carried out with the sample loudspeaker from the previous measurements for an averaging level of 96 dB. The measured distortion was –33 dB (2.2%) and the measured peak level was 108 dB. The second measurement from Fig. 10 was carried out with an average level of 109.7 dB. The peak level was now 122.4 dB and the proportion of total distortion was –20 dB corresponding to 10%. The speaker's 800 Hz weakness is also evident here. The distortions at low frequencies, consisting primarily of harmonic k2 and k3 components, are somewhat concealed in the blue distortion components' local maximum between 100 and 300 Hz. These would be even easier to detect with a sinusoidal burst measurement, but are still recorded correctly here. The multitone measurement confirms the M-Noise measurement at this point, or vice versa: Both measurements provide a maximum level as Leq of 109 dB and – with their limit values of 10% TD for the multitone method or a maximum of 2 dB compression for M-Noise – show where the loudspeaker has its limits. The peak levels measured are 124.7 dB (M-Noise) and 122.4 dB (multitone) respectively. The difference for this measured object is smaller than expected, because the 6 dB gain at peak level is only used if the loudspeaker is able to convert M-Noise's crest factor, which was not the case here.

Summary

With M-Noise, Meyer Sound introduces a new test signal for the measurement of maximum loudspeaker levels. Due to the increasing crest factor for the higher frequency bands, M-Noise comes closer to a real music signal than a test signal derived from a pink noise or a multitone signal. The frequency weighting goes along the lines of the known mean spectral distribution for music signals. What is unusual, however, is that there is no level drop down to 20 Hz.

The M-Noise measurement evaluates the frequency-selective power compression in comparison to a measurement of the loudspeaker's linear working range. With a limit value for power compression of 2 dB, it is possible to adequately

Critical view of the measurement: *Is the curve still within the –2 dB tolerance?*

explore a loudspeaker's capabilities. The maximum sound pressure level can be directly derived from the measurement as a peak value and also as an average level. Depending on the loudspeaker's and the associated amplifier's capabilities, M-Noise documents peak values up to 6 dB higher than those measured with a pink noise or multitone signal. This type of measurement is intended to highlight the differences between different loudspeaker models in the reproduction of highly dynamic music. Ideally, M-Noise measurement is carried out in a low-reflection environment. However, this is not absolutely necessary. A measurement in normal rooms is also possible. Nonetheless, the results can then no longer be compared exactly with those of other loudspeakers or measurements from other rooms. Our measurements were carried out using the Monkey-Forest measurement system, in which the measurement and evaluation of the frequency-selective power compression with M-Noise could be implemented in a few simple steps.

FAQ: 10 questions about the M-Noise

Can one simply convert existing measurements?

No. Existing measurements are made according to various standards and are hardly comparable anyway. The basic requirement for comparability is the measurement signal used. M-Noise uses a test signal with a spectral composition and a frequency-dependent crest factor that has not been used before.

Are results using M-Noise generally higher or lower than previous measurement methods?

Depending on the performance of the midrange/tweeter unit and its amplifier, the SPL peak values are up to 6 dB higher. The averaging levels determined with M-Noise are similar to measurements using an EIA-426B noise or a multitone signal.

Does M-Noise help to better detect power compression?

Indirectly, yes. An early high power compression at the averaging levels also leads to lower peak SPL values according to M-Noise method.

Does M-Noise also make sense for amplifier measurements?

Rather not. Amplifiers already have various standards for determining continuous and peak power as well as power for signals with different crest factors. See our amplifier tests!

For which applications does M-Noise provide more practical values?

For highly dynamic and percussive music.

In which cases does M-Noise also fail to map the performance potential to a condensed single value?

Like all other measuring methods, M-Noise can only display an averaged load condition: Above all, the measured value is a comparison value for different loudspeakers under reproducible conditions. In practice, however, these conditions (classical, rock, techno, language, cinema ...) can be very different.

What is more meaningful than data based on the M-Noise methodology?

That strongly depends on what you want to know: Data about the distortions too? Then the multitone measurement EIA-426B is more meaningful.

Would you like to identify a loudspeaker's individual weaknesses?

Then a sinusoidal burst measurement is more suitable. Is it all about speech reproduction? Then you should use a speech spectrum and so on.

Which manufacturers already publish data according to this measurement?

In this early phase of the proposal, Meyer Sound is in discussions with other sound system manufacturers and distributors as well as with suppliers of measuring instruments.

Will Production Partner also provide results using M-Noise in the future?

We will pursue this further and initially gather more metrological experience for ourselves. We will then decide whether a M-Noise measurement will provide further relevant information beyond what is possible with sinusoidal burst and multitone measurements.

Is this just a manufacturer "trick" to achieve higher data sheet specifications?

No. The main aim is to better represent the possible dynamics that a loudspeaker can reproduce as a value.