A PORTABLE LOUDNESS-METER BASED ON ISO 532B

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Loudness has been found to be the most appropriate measure for the assessment of noise pollution (Zwicker, 1959, 1966, Weber and Mellert, 1978, Fastl 1981, Schaefer 1981, Zwicker and Fastl, 1982). By comparison to other measures such as sound pressure or sound pressure level, loudness has the great advantage that its size is directly proportional to the size of the loudness sensation. Although loudness is a psychophysical quantity, procedures have been developed and standardized to calculate loudness from physical measurements of octave- or third-octave-band sound pressure levels (ISO 532). These procedures - based on calculations, tables and graphical material - can be used only for sounds, which change very slowly as a function of time. In order to overcome this limitation, a set-up was proposed (Zwicker, 1977), in which the loudness calculation procedure ISO 532B is implemented electronically. The equipment was built in the classical way out of passive filters and analog circuits, and therefore it was relatively heavy. The results agreed very well with those obtained by the calculation procedure. Later, in order to reduce the size of the device and increase its portability, an approximation with only 15 instead of 21 filters was constructed, using this time active filters and analog devices (Zwicker and Daxer, 1981). In a second portable version, we started again with a set of 21 active filters as proposed in ISO 532, but used digital circuitry after the filtering stage. In this way, an accurate meter following the standards (ISO 532, DIN 45631), which was even lighter than the previous model, could be constructed. The device operates as follows: The sound pressure variation is picked up by a microphone, at the input to the loudness meter. The loudness as a function of time can be read directly from a meter, or recorded from the output whose DC-voltage is proportional to loudness. The specific loudness-critical band rate distribution produced with the graphs described in ISO 532B is a powerful tool in fighting noise pollution. Accordingly, this pattern is also displayed on the loudness meter, using a digitally controlled matrix of diodes.

A block diagram of the new loudness meter is shown in Fig. 1. The amplifier, the network switchable to free- or to diffuse-field condition, the filter bank with rectifiers and low passes at the input, as well as the final low pass before the output, are all realized in analog form. The other digital parts of the system are connected to the analog elements using a multiplexed analog/digital and digital/analog converter (not shown in the diagram). The outputs of the 20 remaining channels are sampled

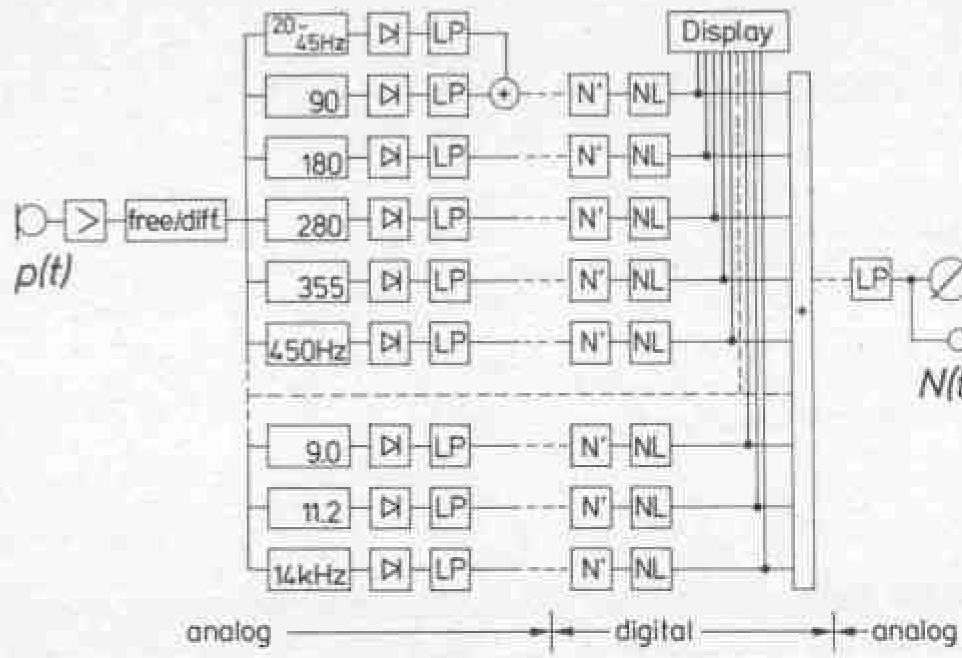

Fig. 1. Block diagram of loudness-meter based on ISO 532B.

about every 3 ms and converted into specific loudness N'. The duration-dependent, i.e. nonlinear decay of N' is realized within the block marked "NL". Then follows a simulation of the level-dependent, i.e. range dependent slopes of the specific loudness-critical band rate pattern, corresponding to the decaying dashed lines in the graphs of ISO 532B. This information is displayed in "real time" as a time dependent specific loudness-critical band rate pattern on an aray of 32x20 diodes. Successively, the specific loudnesses are added together, transformed back into analog form, and fed through a low pass filter. This filter forms the final loudness-time function which corresponds very closely to the sensation elicited by the sound pressure-time function present at the microphone of the loudness-meter.

The following two examples illustrate the usefulness of such a loudness-meter for the control of noise pollution in the specific case of traffic noise.

The loudness produced by a normal truck is compared in the first example with the loudness produced by the same type of truck but noise reduced. The sound pressure produced by the trucks passing by under accelleration (ISO R 362) was fed into the loudness meter. Loudness N as a function of time is graphed for the normal truck (solid) and for the noise reduced truck (dotted) in Fig. 2. The results indicate that the normal truck with 47 sone and 83 dB(A) is almost 50% louder than the noise reduced truck, which reaches a peak loudness of only 32 sone, corresponding to an A-weighted SPL of 75 dB(A).

The second example deals with the often discussed problem of speed limits.A small motorcycle passing by at a speed of 80 km/h produces a peak loudness of 58 sone, which is about 60% larger than that produced bv the same motorcycle at a speed of 60 km/h, namely 36 sone.

Each of the two examples shows a clear reduction of loudness. If the two steps (noise reduction and speed limit) are realized together, a loudness reduction to less than half of the original value would appear. This factor - expressed in loudness values - provides a much better measure of

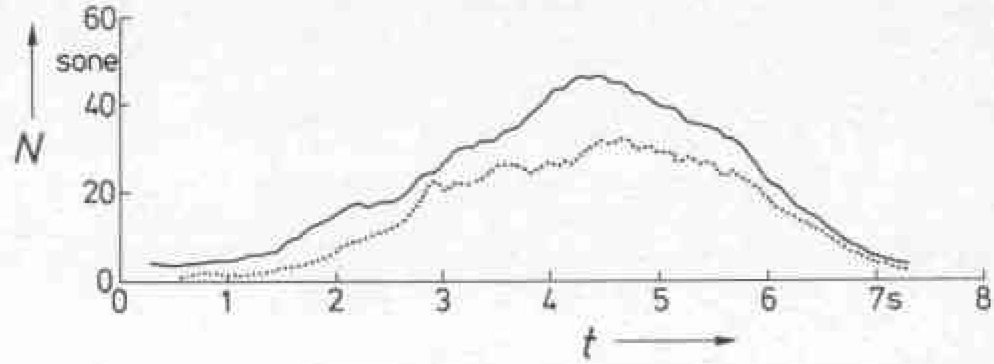

Fig. 2. Loudness-time function of trucks passing accelerated according to ISO R 362. solid: normal truck, dotted: same truck with noise reduction.

what has been achieved by noise reduction than a comparison of two A-weighted SPL values, as for example 85 dB(A) and 74 dB(A).

The direct measurement of loudness is a long needed aid in noise abatement. Until now loudness measurements have only been possible with the aid of bulky equipment and/or tedious graphical procedures. With a small, portable loudness meter (which could run on batteries), the expenditure becomes much smaller and more economical. The proposed small but very accurate loudness-meter carries out the ISO 532B loudness calculation procedure using 5 prescribed ranges, whose maximal loudnesses are 5, 15, 50, 150, and 500 sone. We hope that this loudness-meter will allow noise abatement to be more directly and effectively achieved.

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