A SIMPLE LOW COST ENVIRONMENTAL NOISE ANALYZER FOR THE ASSESSMENT OF TRAFFIC NOISE

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1. INTRODUCTION

In recent years the problem of noise pollution has increased considerably. Complaints may be divided into three main areas - environmental noise, neighbours, and noise at work. Noise in the workplace is the most injurious to health, but this is a preventable hazard which is the subject of the Noise at Work Regulations, and should in time become a thing of the past. Environmental noise such as road, rail or airport noise, is best dealt with at the planning stages in the first instance.

The usual method of monitoring noise is to use an environmental noise analyzer specially manufactured for this purpose. However, there are occasions when the use of these instruments would represent an unnecessary expenditure, and in these circumstances a different method of noise monitoring can be employed. One simple technique is to use a PC with additional inexpensive hardware to sample the noise, and software to analyze the results. A standard IBM AT compatible computer with an analogue to digital converter card (PCL-718) has been used as a simple environmental noise analyzer. The input to the card is taken from any high quality microphone and preamplifier combination with 'A' weighting, such as a sound level meter.

2. CALCULATION OF PERCENTILES

It is not possible to sum percentiles in the same or a similar way to Leq, though this mistake is sometimes made. The following example demonstrates that a one hour Leq cannot be determined from four individual 1/4 hour Leq's.

The graphs in fig. 1 represent sound level against time in a case where the background level is 50dB with occasional events of 70dB lasting for one minute. It may be seen that the one hour Leq in fig. 1(a) is the same as the background level because the total event time is less than 10% of the measurement period. The same applies to each 1/4 hour period. However in fig. 1(b), by the same reasoning the last quarter hour gives an L10 of 70dB, yet the one hour L10 is still 50dB. Fig. 1(c) shows that one further
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Figs. 1 (a), (b) & (c) L10 Example (see text)
(events are 1 min duration)
similar event in the last quarter hour will raise the one hour 
$L_a$ to 70dB even though the individual $\frac{1}{4}$ hour $L_a$'s are exactly the 
same as in fig. 1(b). Similar reasoning will apply to other 
percentiles, eg $L_T$, $L_x$, and it is not therefore possible to 
calculate percentiles without knowing the continuous level/time 
history for the duration of the measurement period. 
The technique here employed of storing levels every $1/8$th second 
means that the level/time history of noise is available for 
subsequent evaluation, and thus enables statistical analysis for 
any section of the measurement period.

3. SOFTWARE

The software for the implementing the noise analyzer (see fig. 2) 
was divided into several small programs. The first program is 
rung when the sound is being input and is written in Turbo C with 
an inline assembler section, which is used to sample the input 
sound at about 77,000 samples per second. All of the other 
programs are used later to analyze the sound in a variety of ways 
and display results graphically or in lists. A noise signal can 
be input to the card from the "AC output" of a sound level meter 
or, alternatively, tapes that have been pre-recorded at a 
particular outdoor location on a portable tape recorder can be 
fed into the system for examination with the analysis programs 
as in the traffic noise examples described later.

The assembler sampling algorithm is extremely simple - sampled 
data from the card are squared and summed (equivalent to the sums 
of the squares of the instantaneous sound pressure) in memory for 
$1/8$th second. A new memory location is used every $1/8$th second 
until 1 hour of data has been stored. At this stage the data in 
memory is transferred to hard disc. The hard disc storage allows 
up to several weeks of continuous monitoring (depending on disc 
capacity), but unfortunately about $1$ second of data is lost every 
hour whilst the transfer of data to disc takes place, although 
this should not alter the final results very much for traffic 
noise monitoring.

The analysis programs can be used after the noise has been 
sampled with the measurement program. The programs written so far 
enable noise levels to be displayed, $L_a$, and percentiles ($L_x$, etc) 
to be calculated, statistical level distribution and cumulative 
level distribution to be displayed graphically or printed, and 
events to be logged. Other software can easily be added to 
calculate other acoustic parameters such as Traffic Noise Index, 
or for estimating aircraft noise indices or examining train 
passes in detail.
The $L_\text{eq}$ over a given period is calculated by the program using the following formula:

$$L_\text{eq} = L + 10\log_{10} \left( \frac{P}{C} \right) - 10\log_{10} \left( \frac{1}{T} \right)$$

$L$ = Calibration Level
$P$ = Sum of Squared Pressure Values
$C$ = Calibration Squared Pressure (1/8th Sec)
$T$ = Time Period of $L_\text{eq}$ (Seconds)

Note that the factor of 10 rather than 20 is used since we are dealing with the squares of pressures.

The values of $L$ and $C$ are written to the calibration file at the measurement stage and are read in by the analysis programs when these are run. Thus it is clearly a simple matter to find the $L_\text{eq}$ over any duration within the measurement period.

The percentiles have been calculated using an array of 1300 elements (representing consecutive sound pressure levels up to 130 dB in 0.1 dB steps) to store the number of 1/8th second occurrences of that sound pressure level over a given time period. The $L_\text{eq}$, for example, is then found by summing the values stored in the array elements from the bottom of the array until 90% of the total number of occurrences have been counted and 10% are left. The element number at which this occurs represents the $L_\text{eq}$ (eg. element 683 is 68.3 dB). The array data are also used to calculate level and cumulative distributions for graphical output.

4. SPECTRUM ANALYSIS

It is also possible using an A/D card to perform spectrum analysis on noise signals with suitable FFT software. Generally, traffic noise has maximum energy at about 100 Hz, but the frequency characteristics will change slightly with traffic speed, weather conditions and percentage of heavy vehicles. Spectrum analysis is not particularly valuable for traffic noise assessment because annoyance is more a factor of noise levels.

In order to analyze the complete audio spectrum, it is necessary to sample unweighted noise at about 40 kHz. A problem with sampling at this rate is the amount of computer memory usage. However, since traffic noise is non-repetitive it is possible to superimpose several "layers" of sound and carry out the analysis on the resulting signal. A standard FFT routine [1] has been adapted for use directly on the stored data gives a similar
Calibration — Input date, time, calibration level, measurement position etc. Play calibration tone of stated level into A/D card for 5 seconds

Pressures are sampled, squared and added — Divided by 40 to give the 1/8 th second mean squared pressure of the calibration tone

This mean squared pressure together with its stated level and other information are transferred to hard disk file 'CALDATA' for later use by the analysis programs

Measurement — (Start date & time may be preset.) Noise is input via microphone or tape and sampled by A/D card at about 77000 samples per second

Samples are squared and added in 1/8 th second periods and stored in consecutive computer memory locations for up to 1 hr at a time

1/8 th second mean squared pressures are transferred to hard disk storage once per hour until requested duration is reached (could be several days or weeks)

Input start date, time and duration for which analysis is required. An array of dimension 1300 is initialized representing sound levels 0–130dB with 0.1dB resolution. The file pointer is moved to relevant section of data

Disk pressure data are read and converted into levels. For each occurrence of a particular level the corresponding array element contents are incremented by 1

The contents of array elements are summed along the array ...
... for example an L50 will correspond to element where 50% of the total samples is reached. Simple calculations on the array give Level & Cumulative charts

Fig. 2a DATA ACQUISITION PROGRAM

Fig. 2b STATISTICAL ANALYSIS PROGRAM
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spectrum display to a commercially available FFT analyzer, although the latter has many more facilities.

5. TEST RESULTS AND INTERPRETATION

To check the accuracy of the "Environmental Noise Analyzer" and to show the differences between typical traffic noise profiles, recordings were made and readings taken at two roadside locations. The two chosen locations were:
1] a residential suburban road (Ordnance Survey ref. TQ42358757) about 70m away from the North Circular but without much traffic of its own.
2] the A12 trunk road (TQ41438837) close to the start of the M11 motorway

All recordings were made for a period of one hour at a distance of 2m from the kerb using a Brüel & Kjær 2231 Sound Level Meter connected to a portable digital tape recorder. The suburban road was monitored during the day (15.00 - 16.00) and the A12 was monitored at day (15.00 - 16.00) and night time (01.00 - 02.00).

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**Fig. 3(a) Statistical Analysis – Suburban Residential Road**
Fig. 3(b) Night, 3(c) Day Statistical Analysis – A12 Traffic
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The accuracy when compared with the 2231 readings for percentiles was typically better than 0.5dB(A), though the B27101 module has a resolution of 0.5dB for percentiles. Max L and Min L were occasionally in error by a somewhat larger amount. Computed values for Lₚₚ usually matched instrumentation within 0.2dB.

Figure 3 shows the level distribution (histogram) and cumulative distribution (line graph). Although various level distribution increments are permitted in the software, 1.0dB steps are shown in these examples. A cumulative distribution is displayed in 0.1dB steps and thus appears as a continuous line. The vertical axis of each graph is denoted "percentage time" and divided into ten. For the cumulative distribution the top of the axis represents 100%, whilst for the level distribution it represents the percentage of the Mode (ie the percentage of time of the most frequently occurring sound level).

The cumulative distribution line graph may be used to find any required percentile. For example to find the L₂₅ mark off 25% of the vertical axis distance and draw a line horizontally until it intersects the curve. This position on the Level axis will represent the L₂₅.

In the cases of the particular results shown, we can see that for the first location, graph 3(a) indicates that there is a fairly constant level which has predominated throughout the measurement period - the level step at 56dB occurs for almost 24% of time. This feature of the example is attributable to the proximity of the North Circular Road which gave a constant background noise, and the relatively little traffic on the residential road (approximately 100 cars during measurement).

Graphs 3(b) and 3(c) are analyses of A12 traffic at location 2, and show the night/day variation. The night graph 3(b) shows a large proportion of noise below 60dB(A), and a clear indication of a background level of about 53dB(A). In the day graph 3(c), the noise is above 60dB(A) and the background level is not obvious due to the wide spread of noise levels. Figures 3(a), (b) and (c) show that the effect of progressively increasing the number of vehicles is to increase the prominence of a "crest" at the higher sound levels which is not present on figure 3(a).

6. REFERENCE
