同济大学研究生毕业论文

题目：飞机、道路噪声微机自控分析仪的研制（详细摘要）

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THE DEVELOPMENT OF MICROCOMPUTER AUTOCONTROLLED ANALYZER ON AIRCRAFT AND ROAD NOISE

DETAILED ABSTRACT

In the development of the modernization construction courses in our country, the noise problems have been growing more and more serious. Although many works have been done in the road traffic noise study and harnessing, the study and harnessing works on the aircraft noises are still a weakpoint, especially in the development of the aircraft noise measuring instruments, hence, the works in the area are extremely needed to be enhanced. In order to meet the requirements of measuring the aircraft noises to promote the study works of the aircraft noises and bring them under control, by using a single board computer, an instrument which is mainly used for measuring the aircraft noises has been developed. The devolopment of the instrument involves two parts, one is the analog and digital acoustical measuring circuits which interface with the microcomputer (hardware), the other is the special programs used for the measurement control and datum processing of the instrument (software). In the development of the hardware, some special circuits which interface with the microcomputer have been designed and some available hardware circuits have been improved. In the development of the software, some functions such as auto-judgement, auto-analysis, autocontrol and automatic datum processing are added, and some new datum processing and program design methods which are adapted to measure the aircraft noises are adopted, and thus, the instrument achieves some functions that foreign similar instruments have not achieved. Except the aircraft noise measurements, the road traffic noises and other noises can also be

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measured by the instrument.

一 . THE DEVELOPMENT OF THE INSTRUMENT AND THE DEFINITIONS OF SOME MAJOR ACOUSTICAL CRITERIA

1. THE DEFINITIONS OF AIRCRAFT NOISE CRITERIA

According to International Standard ISO/3891, several criteria used mainly for aircraft noises are defined as following:

(1) Perceived Noise Level L_{PN}

$$L_{PN} = 10 \log_2 N + 40$$

where $N = 0.85\ n_{max} + 0.15 \sum_{j=1}^{24} n_j$. The n_j represents the perceived noisiness of the jth one-third octave band sound pressure level which center frequency ranges from 50Hz — 10,000Hz, and its value is determined by the perceived noisiness contours and the spectrum of the noise.

(2) Tone - corrected Perceived Noise Level L_{TPN}

$$L_{TPN} = L_{PN} + c$$

where c is a tone correction and its evaluation is very complex and it will not be discussed in detail here. The meaning of the evaluation of the tone correction is the equivalent value (dB) of the difference between the smoothed and unsmoothed noise spectra.

(3) Effective Perceived Noise Level L_{EPN}

$$L_{EPN} = 10\lg\left(\frac{1}{T_0}\int_{-\infty}^{+\infty} 10^{L_{TPN}/10}\,dt\right)$$

where T_0 is chosen as 10s according to International Standard ISO/3891, and the L_{EPN} is mainly used for an aircraft flyover noise assessment.

(4) Equivalent Peceived Noise Level L_{PNeq}

$$L_{PNeq} = 10\lg\left(\frac{1}{T}\int_0^T 10^{L_{PN}/10}\,dt\right)$$

where T is the time during which the measurement lasts, and the L_{PNeq} is mainly used for the long-term aircraft noise exposure assessment.

2. THE DEFINITIONS OF SEVERAL OTHER CRITERIA

(1) Cumulative Distribution Level L_N

The cumulative distribution level L_N means that there are N percent noise levels exceed the L_N during the time the measurement lasts. If N is chosen as 10, 50 and 90 respectively, the L_{10}, L_{50} and L_{90} may be obtained.

(2) Equivalent Continuous Sound Level L_{eq}

$$L_{eq} = 10lg\left(\frac{1}{T}\int_0^T 10^{L_A/10}dt\right)$$

where T is the time during which the measurement lasts, and L_A is the A - weighted sound level. $L_A = 20lg\frac{P}{P_o}$, where P is the A-weighted sound pressure, and P_o is the reference sound pressure and its value is 2×10^{-5} P_a.

(3) Noise Pollution Level L_{NP}

$$L_{NP} = L_{eq} + 2.56\sigma$$

where σ is the standard deviation and defined as

$$\sigma = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(L_{Ai}-\bar{L}_A)^2}$$

, N is the total sample number and $\bar{L}_A$ is the arithmetic mean value of the L_A in the measuring time.

(4) Traffic Noise Index TNI

$$TNI = 4(L_{10}-L_{90}) + L_{90}-30$$

3. THE BLOCK DIAGRAM OF THE INSTRUMENT

Figure 1 shows the block diagram of the instrument.

4. HARDWARE DEVELOPMENT

In order to make the computer be used for the acoustical measurement purposes, some peripheral circuits which interface with the computer have been developed. They are the electronic switch and its controller, the four digital LED display and front panel operation console, and the computer interface circuit of the analog to digital converter etc. Besides, an available logarithm amplifier circuit has been analyzed and then been improved, and its characteristics become so sophisticated that it meets the technical requiements of the instrument.

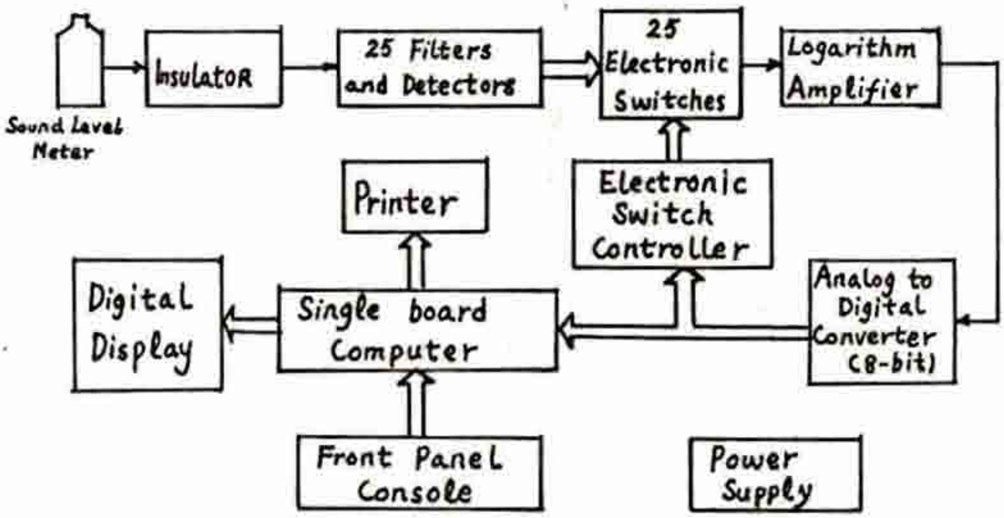

Figure 1. The block diagram of the instrument

二. SOFTWARE DEVELOPMENT

1. THE BLOCK DIAGRAM OF THE PROGRAM

Figure 2 shows the block diagram of the program.

2. A BRIEF INTRODUCTION OF THE PROGRAM DESIGN

The instrument is centered by the computer and all of its measurements are directly controlled. Hence, the datum analyses and datum processing abilities of the instrument depend largely on the program design. The major features of the program design are summed below:

(1) A programable timer has been used in the instrument and it is connected with the programs in an interruption mode. The advantage of the interruption operation mode is that the computer can process a great deal measuring data during the timing and turn to deal with the interruption service routine only when an interruption occurs. The timing period can be changed according to different requirements in the instrument.

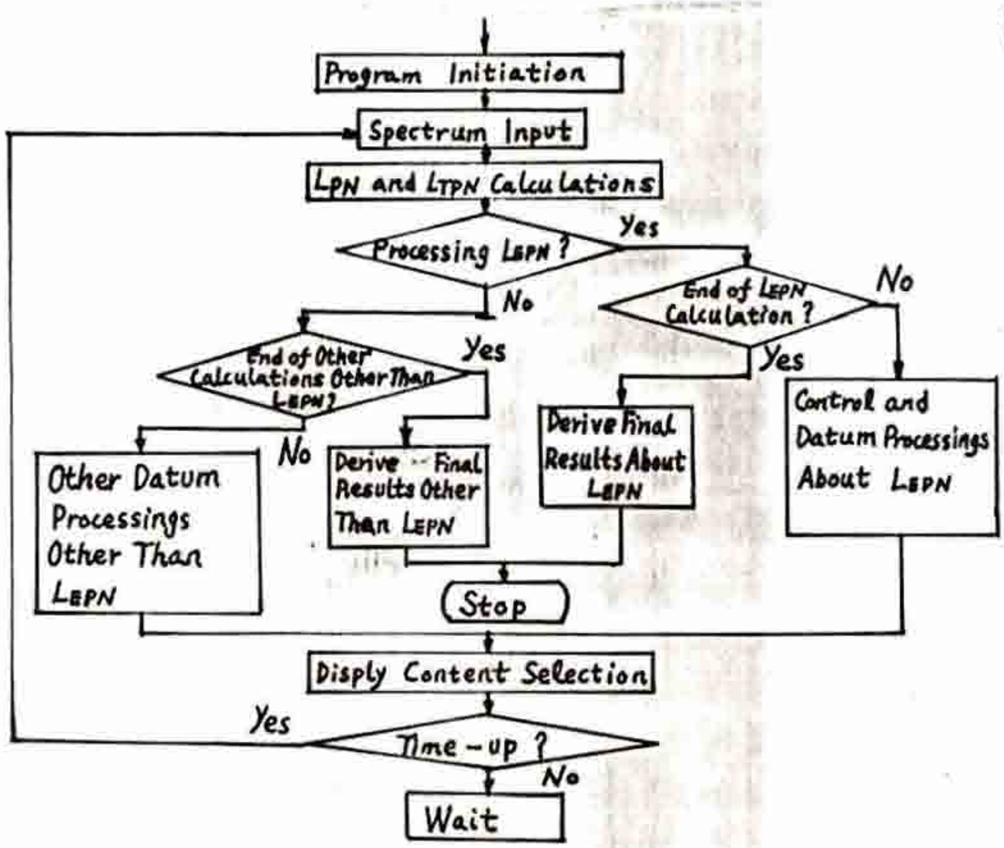

Figure 2. The block diagram of the program

(2) In order to process a great deal spectrum data without taking up a lot of computer memory space, the method which the data are processed as the measurement is undertaking is

adopted by the instrument. This can be seen in Figure 2. When the spectrum is inputted, the program will first process it to obtain the L_{PN} and L_{TPN}. At this time, the spectrum can be updated by next spectrum because other processings referring to the spectrum depend only on the L_{PN} and L_{TPN}. For further long-time processings of the L_{PN} or the L_A without taking up a lot of computer memory space, the instrument accumulates a new processed sample to the accumulation of the former processed samples when a new sampling occurs, thus, the integrations defined before can be completed while taking up a little computer memory space.

(3) The L_A, L_{PN} and L_{TPN} can be digitally displayed at any time when the instrument is used for the field measurements. Because of this function, the L_{PN} and L_{TPN} can be conveniently read out in the instrument whenever necessary just like a digital sound level meter, thus, the time relations of the L_{PN} and L_{TPN} can be observed.

(4) The instrument can automatically get rid of some kind of interferences. For example, if a short duration interference signal happens to occur during the measurement of the aircraft flyover noise before the flyover procedure has begun, the instrument will not mistake the interference signal for the aircraft flyover noise signal if the duration time of the interference signal level over a preset level in the instrument is less than two seconds, and the instrument will clear up the stored interference signal so that the L_{TPN} values can be stored when the flyover procedure has really begun.

(5) After an aircraft flyover begins, if a high sound level lasts for a long time and if the duration time exceeds six minutes and twenty-four seconds, the instrument will automatically judge that it is not a flyover procedure and will print out error messages to indicate that the measure-

ment must be over again.

(6) If the maximum tone-corrected perceived noise level does not exceed the background noise level plus 20 dB during the whole flyover procedure, the instrument will also give the datum fault messages.

(7) Various measurements can entirely be automatically controlled in the instrument. As in the aircraft flyover noise measurements, the instrument can automatically determine the beginning and end of the flyover procedures, thus, the uncertainty of human judgement can be avoided, and hence the reliability and consistency of the results will be increased. For the measurements that their results can be obtained only after long duration time, the measurements can also be controlled automatically by the instrument. By presetting a measurement duration time (sample numbers X sample period), by the end of the measurement the instrument will automatically print out the measurement results and then stop itself.

(8) The electronic switch, analog to digital converter, digital display and front panel console switches are all controlled by the program, and the hardware circuits are replaced as many as possible by the software in the interfacing circuit designs, so that the hardware circuit designs are greatly simplified, and the costs have been cut back, hence, the realiability of these circuits are increased.

(9) From the program block diagram (Figure 2), it shows that although the L_{PN}, L_{TPN} and L_{PNeq} are mainly used for the aircraft noise assessment, the L_{PN} and L_{TPN} can be obtained by each sampling and L_{PNeq} can also be obtained whenever the criteria L_N, L_{eq}, L_{NP} and TNI are obtained. Therefore, the application scopes of the L_{PN}, L_{TPN} and L_{PNeq} as well as the relationship between these criteria and other criteria can be studied by making use of the

characteristics of the instrument.

(10) Although the instrument is mainly used for measuring the aircraft noises, it is also an noise level analyzer. It contains the major functions of Danish Noise Level Analyzer Type 4426, besides, the L_{NP} and TNI can be obtained directly. Thus, the instrument is a multifunctional measurement and analysis instrument and will find wide applications.

三. THE RESULTS OF THE EXPERIMENTS AND DISCUSSIONS

In order to test the performances of the instrument, the aircraft flyover noises and the road traffic noises are recorded on Jiangwang Airport and Dalian Road respectively.

The variation relation between the L_{TPN} and t (time) in some aircraft flyover procedure is given in Figure 3, and it can be seen that the measuring values are quite close to the values obtained by the manual calculation and their variation tendency is almost the same. In addition, some eight more aircraft flyover noises are also analyzed in this way and no details will be given here.

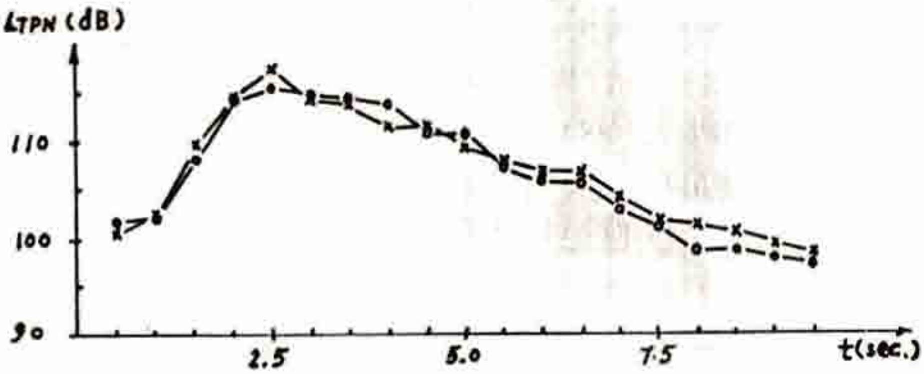

Figure 3. L_{TPN}-t relation of one aircraft flyover procedure
× — The values measured by the instrument
o — The values produced by the manual calculation

The manual calculation L_{EPN} values and those measured by the instrument and their differences are tabulated in Table 1.

ith Aircraft	1	2	3	4	5	6	7	8	9
Manual Calculation Values (dB)	110.0	111.4	102.6	109.9	110.0	112.0	104.5	111.5	112.6
The Values Measured By the Instrument (dB)	110.0	111.9	102.9	110.1	110.3	113.3	104.2	111.3	110.9
Differences (dB)	0.0	+0.5	+0.3	+0.2	+0.3	+1.3	-0.3	-0.2	-1.7

Table 1. The comparisons between the manual calculation values and those measured by the instrument

The comparisons of the analyzed results between the instrument and Danish B&K Noise Level Analyzer Type 4426 are given in Table 2. (The sample period is 0.5 second and the sample numbers are 2,000). The symbol "△" means the differences of the results.

Recording Number	1	2	3	4	5	6	7
ΔL_{10} (dB)	0.0	0.0	-0.3	+0.2	+0.7	+0.2	0.0
ΔL_{50} (dB)	+0.2	+0.2	+0.2	+0.2	+0.5	+0.2	+0.2
ΔL_{90} (dB)	+0.4	+0.2	-0.1	+0.4	+0.5	+0.2	0.0
ΔL_{eq} (dB)	+0.2	+0.1	+0.1	+0.4	+0.9	+0.3	0.0

Table 2. The comparisons of the analyzed results between the instrument and B&K Noise Level Analyzer Type 4426

For other criteria derived from the L_{PN}, L_{TPN} and L_A, their calculating programs have been proved by a lot of realiable data, and their testing results will not be given here.

The instrument has provided a good method for the aircraft noise measurements, but the hardware designs and their making technologies are to be further improved so that it can be found practical applications.

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飞机道路噪声微机自控分析仪的研制（详细摘要）

随着我国现代化建设事业的发展，噪声污染日益严重。对道路交通噪声的研究和治理已经做了许多工作，但对飞机噪声的研究和治理还比较落后，尤其在飞机噪声的测量仪器的研制方面还是空白。因此这方面的工作极待加强。为了满足飞机噪声的研究和治理工作对飞机噪声测量仪器的需要，我们利用单板微处理机研制了一台以测量飞机噪声为主的仪器。该仪器的研制包括与微处理机相接口的模拟和数字声学测试电路（硬件）的研制和用于整机测量控制和数据处理的专用程序（软件）的研制。在硬件研制中设计了一些与微处理机相接口的专用电路，并改进了一部分现有的硬件电路。在软件研制中增加了一些自动判断、自动分析、自动控制和自动数据处理的内容，采用了一些与飞机噪声测量相适应的新的数据处理方法和程序设计，增加了一些国外同类仪器所没有的功能。除了测量飞机噪声外，本仪器还能够测量道路交通噪声和其它噪声。

一．仪器的研制和它能测量的几个主要声学评价量的定义

1．几个主要用于飞机噪声的评价量的定义

(1) 感觉噪声级 L_{PN}

$$L_{PN} = 10\log_2 N + 40$$

式中：$N = 0.85n_{max} + 0.15\sum_{j=1}^{24} n_j$，$n_j$ 表示中心频率 50HZ ~ 10,000 HZ

的24个1/3倍频带声压级所相当的吵闹度，其值由等感觉吵闹度曲线和噪声频谱共同决定。

(2)纯音修正感觉噪声级L_{TPN}

$$L_{TPN} = L_{PN} + C$$

式中C是纯音修正量，它的求法比较复杂，此处不详述。但它的意义表示原频谱与经过匀滑后的频谱之间差别引起的闹度所相当的分贝数的最大值。

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(3)有效感觉噪声级L_{EPN}

$$L_{EPN} = 10\lg\left(\frac{1}{T_0}\int_{\infty}^{\infty} 10^{L_{TPN}/10}dt\right)$$

式中T_0按国际标准ISO/3891取为10秒。

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L_{EPN}主要用于飞机飞越噪声的评价。

(4)等效感觉噪声级L_{PNeq}

线

$$L_{PNeq} = 10\lg\left(\frac{1}{T}\int_0^T 10^{L_{PN}/10}dt\right)$$

式中T是测量持续的时间。

L_{PNeq}反映了长期的飞机噪声暴露级。

2. 其它几个评价量的定义

(1)累积分布声级L_N

L_N表示在整个测量过程中有N%的声级超过L_N。取N = 10，50和90，即得L_{10}，L_{50}和L_{90}。

(2)等效声级L_{eq}

$$L_{eq} = 10\lg\left(\frac{1}{T}\int_0^T 10^{L_A/10}dt\right)$$

式中T表示测量持续的时间，L_A表示A计权声级。

$$L_A = 20\lg\frac{P}{P_0}$$

式中P_0为参考声压值，取值2×10^{-5}帕。

(3)噪声污染级L_{NP}

$$L_{NP} = L_{eq} + 2.56\sigma$$

其中

$$\sigma = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(L_{Ai} - \overline{L}_A)^2}$$

式中N是总采样数，$\overline{L}_A = \frac{1}{N}\sum_{j=1}^{N} L_{Aj}$表示$L_A$的算术平均值。

(4)交通噪声指数TNI

$$TNI = 4(L_{10} - L_{90}) + L_{90} - 30$$

3．仪器总框图

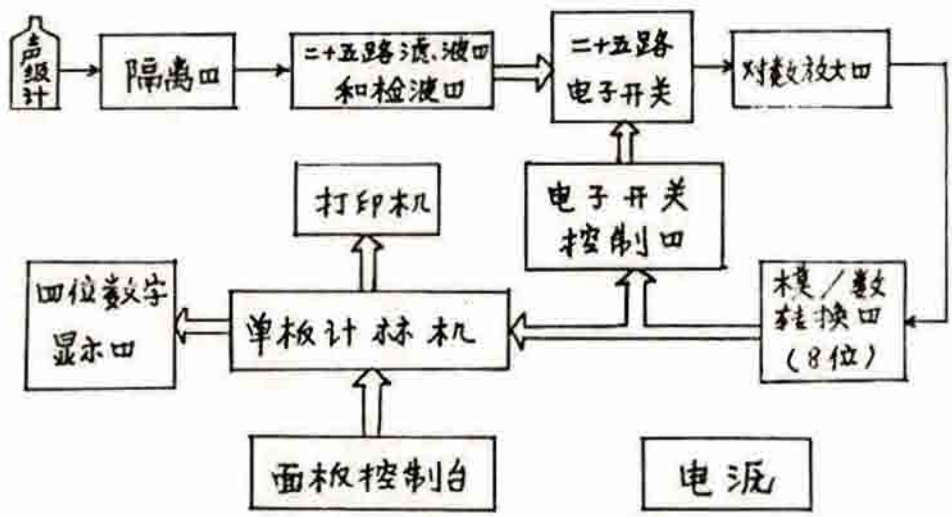

图1．仪器总框图

4．硬件研制

为了使计算机能用于声学测量，我们研制了一些与计算机相接口的外围电路。其中主要的有：电子开关、电子开关控制器、四位数字显示器、面板操作控制台以及模数转换器件与计算机的接口电路等。并对现有的对数放大器电路经过分析后加以改进，使其性能更加完善，满足了本仪器对它的要求。

二．软件开发

1．程序总框图

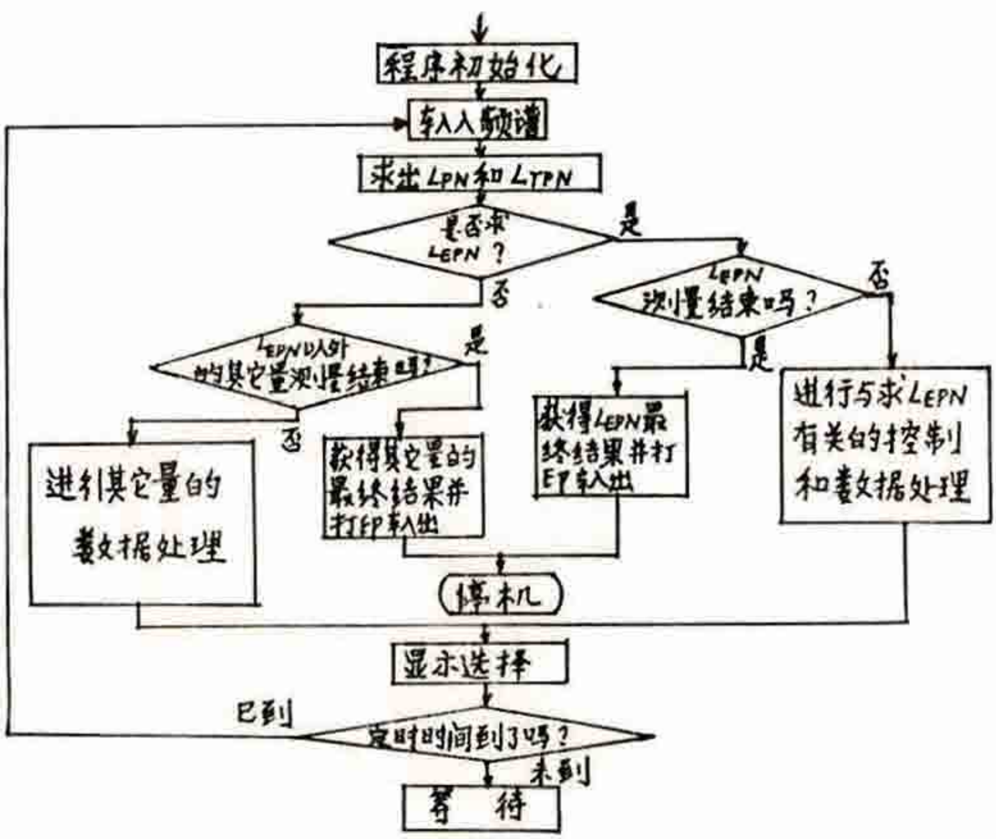

图2．程序总框图

2. 程序设计简介

本仪器是一台以计算机为中心的仪器，一切测量都在计算机的直接控制下进行。因此仪器的数据分析和处理能力很大程度上取决于程序设计。下面对本程序设计的主要特点作一简单的介绍。

(1) 本仪器采用可编程时钟作定时器，它以中断的方式与整个程序连系在一起。中断工作方式的好处是在定时期间计算机还能够处理大量的测量数据，只在中断时计算机才转入处理与定时有关的中断服务程序。本仪器的定时器还可根据不同的需要选择不同的定时时间。

(2) 为了对大量的频谱进行数据处理，本仪器采用边测量边处理的方法，使频谱占用的内存量大大减少。这可从图 2 所示的程序总框图看出：频谱一经输入，首先经过求 L_{PN} 和 L_{TPN} 程序将它们转变成两个量，由于下一步与频谱有关的处理仅依赖于 L_{PN} 和 L_{TPN}，因此求出 L_{PN} 和 L_{TPN} 后频谱可被更新，在下一个采样时刻到来时，新频谱就代替了原有的频谱。为了要进一步对 L_{PN} 或 L_A 作长时间的处理而又要少占计算机的内存量，本仪器使用采样一次累加一次的方法，使累加后的新值去取代累加前的值，这样就可完成前述测量量的积分过程，而占用很少的计算机内存。

(3) 从程序总框图可以看到，在现场测量的任何时候，都可以显示该时刻的 L_{PN}、L_{TPN} 和 L_A 值。由于这一功能，本仪器能够象数字式声级计那样方便地随时读出 L_{PN} 和 L_{TPN} 值，从而可以观察 L_{PN} 和 L_{TPN} 随时间的变化关系。

(4)本仪器还能自动排除某些干扰。例如在测量飞机飞越噪声时，如果飞越过程还未开始，而这时出现持续时间短暂的干扰信号，如果它的声级超过仪器所设定的某个声级的持续时间不超过两秒钟，那么仪器不会误认为是飞机飞越噪声的开始，并且将把已经存入计算机的干扰信号的声级值清除掉，以便在真正飞机飞越过程开始时存放L_{PN}的采样值。

(5)如果仪器判别飞机飞越过程开始后，出现持续时间较长的高声级这种不属于飞机飞越的情况，如果其持续时间超过6分钟24秒，仪器将会打印出错信息，表明测量必须重新开始。

(6)在测量飞机飞越噪声时，如果在整个飞越过程中的最高声级不大于本底噪声20分贝，本仪器将打印出数据无效的信息。

(7)本仪器能自动控制各种测量过程。如上述测量飞机飞越噪声时，仪器能够自动判断飞机飞越过程的开始和结束，避免了人为判断的不便，提高了结果的可靠性和一致性。对其它一些需要长时间采样才能得到测量结果的测量，仪器也能进行自动控制。只要选择好测量持续时间（采样数×采样周期），在测量结束时，仪器就会自动打印出所要的结果并自行停机。

(8)本仪器的电子开关、模/数转换、数字显示和面板操作开关等都由程序进行控制，并在接口电路设计中尽量以软件代替硬件电路，从而大大简化了硬件电路的设计，降低了费用，提高了电路的可靠性。

(9)虽然L_{PN}、L_{TPN}和L_{WECPN}等量主要用于评价飞机噪声，但从程序总框

图可以看到，每次采样都能得到L_{PN}和L_{TPN}，在测量L_N、L_{eq}、L_{Np}和TNI时也同时能够得到L_{PNeq}。因此，可以利用本仪器这一特点，进一步研究这些量与其它一些噪声评价量之间的关系，以及它们的适用范围。

(10)虽然本仪器主要用于飞机噪声的测量，但它实际上还是一台噪声级分析仪，包括了丹麦B&K 4426噪声级分析仪的主要功能，除此之外还能直接获得L_{Np}和TNI，因此本仪器是用途广泛的多功能的噪声测试分析仪器。

三. 试验结果和讨论

为了验证仪器的性能，我们在江湾飞机场和大连路分别进行了飞机飞越噪声和道路交通噪声的现场录音。

图3给出了某次飞机飞越过程中部分L_{TPN}值随时间t的变化关系。从中看到测量值和计算值符合得很好，其变化规律大致相同。此外，还测量了八架飞机的飞越噪声，其手工计算值也与测量值符合得很好，这里就不一一画出了。

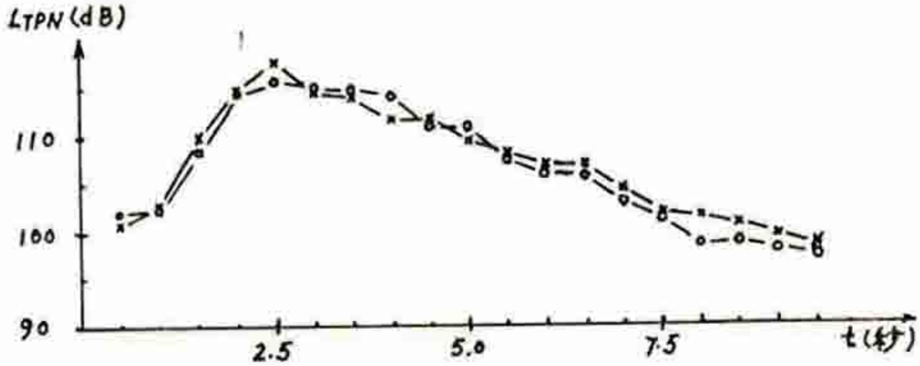

图3. 某次飞机飞越过程中L_{TPN}～t的变化规律
×——由本仪器测出值
o——由手工计算得出的数据

表1列出了 L_{EPN} 的仪器测量值和手工计算值以及它们之间的差别。

飞机架次	1	2	3	4	5	6	7	8	9
手工计算值（dB）	110.0	111.4	102.6	109.9	110.0	112.0	104.5	111.5	112.6
仪器测出值（dB）	110.0	111.9	102.9	110.1	110.3	113.3	104.2	111.3	110.9
误差（dB）	0.0	+0.5	+0.3	+0.2	+0.3	+1.3	-0.3	-0.2	-1.7

表1. L_{EPN} 手工计算值与仪器测出值的比较

表2给出了本仪器对现场录音的交通噪声信号测量分析结果与丹麦 B&K 4426 噪声级分析仪测量分析结果的比较。（采样周期为0.5秒，采样数目为2000）。表中"Δ"表示结果的差值。

录音编号	1	2	3	4	5	6	7
ΔL_{10} (dB)	0.0	0.0	-0.3	+0.2	+0.7	+0.2	0.0
ΔL_{50} (dB)	+0.2	+0.2	+0.2	+0.2	+0.5	+0.2	+0.2
ΔL_{90} (dB)	+0.4	+0.2	-0.1	+0.4	+0.5	+0.2	0.0
ΔL_{eq} (dB)	+0.2	+0.1	+0.1	+0.4	+0.9	+0.3	0.0

表2. 本仪器与 B&K 4426 噪声级分析仪测量分析结果的比较

对于其它由 L_{PN}、L_{TPN}、L_A 导出的量，它们的计算程序已有可靠的数据证明是正确的，对它们的检验此处从略。

本仪器为测量飞机噪声提供了很好的测试手段，但在硬件电路的设计和制作工艺上有待进一步完善，以便取得实际推广使用。

一九八四年七月

堪误表		
页，行	错误	正确
英3,7	by	be
中4,图2	→[输入频谱]	→[输入频谱]
中5,2	计	机
中5,3	进	进行