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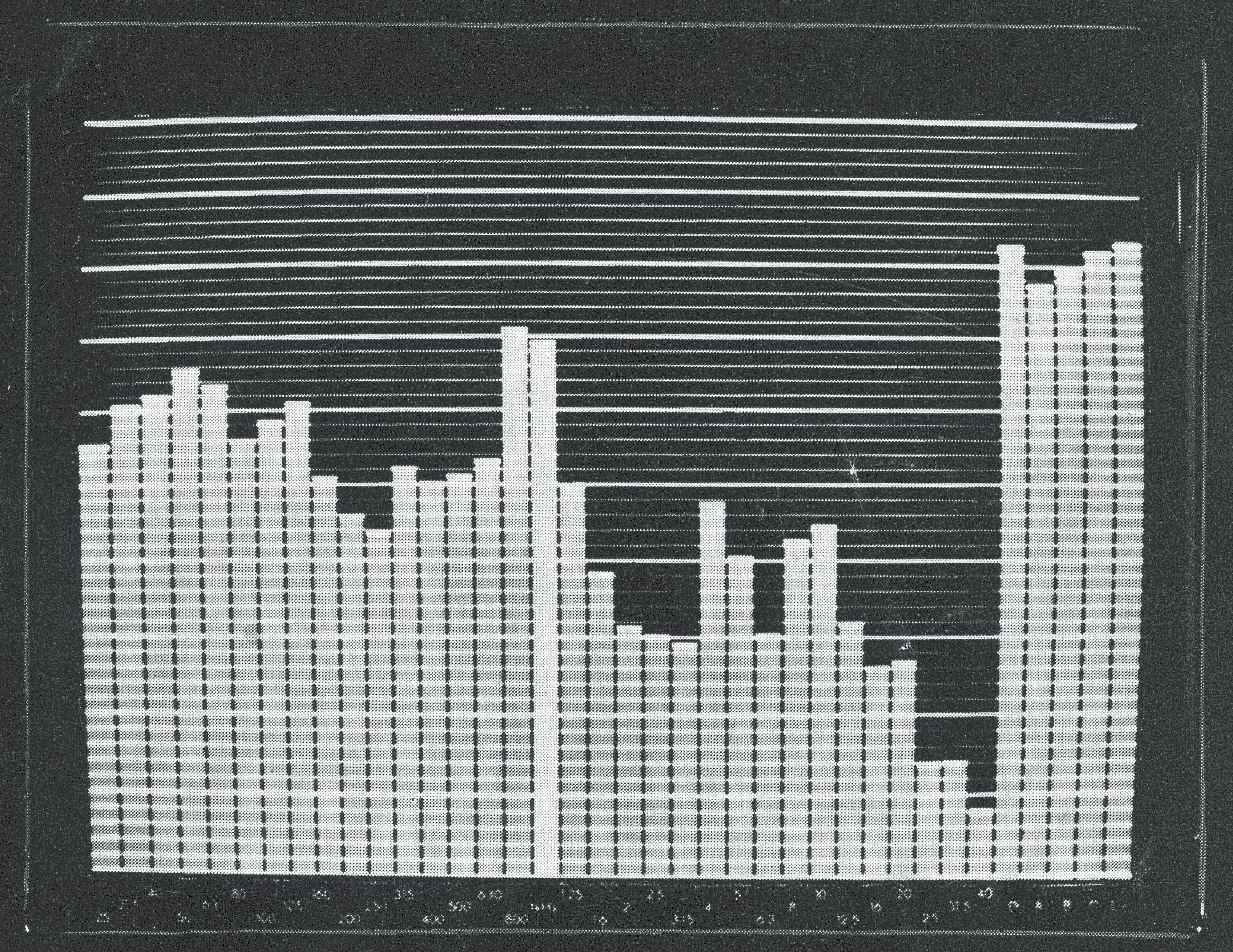

Real-Time Analysis

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TECHNICAL REVIEW

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Contents

Real Time Analysis

by

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ABSTRACT

This article describes a system of making an acoustical or vibrational spectrum analysis in an automatic mode using the newest developments in analog and digital technology. The method also makes it possible for the first time to read the spectrum in time coincidence with respect to the "scan start" signal. The spectrum ranges from 25 Hz to 20 kHz and the output is available in both analog and digital mode which makes the system useful in connection with existing analog level recorders as well as any type of digital equipment available today or in the forseeable future including punchers, printers, instrumentation computers etc. It is also pointed out that the analog display tube is bright and clear without the possibility of being misread due to parallax errors, since scale lines are processed electronically.

At the end of the article the execution of a computer data transfer is described. The maximum execution time required for this is approximately 2 msec for all 38 frequency channels and one reference channel.

SOMMAIRE

Cet article décrit un système rendant automatique une analyse de spectre acoustique ou de vibrations et faisant appel aux tout nouveaux progrès en technologie analogique et digitale. La méthode rend aussi possible, pour la première fois, de lire le spectre en coïncidence de temps par rapport au signal de départ du balayage. Le spectre va de 25 Hz à 20 kHz et la sortie est disponible dans les modes analogique et digital, ce qui rend le système utile en liaison avec des enregistreurs de niveau analogiques existants, somme n'importe quel type d'équipement digital disponible aujourd'hui ou dans le futur, y compromis les perforatrices, imprimantes, ordinateurs d'instrumentation, etc. A noter également que le tube d'affichage analogique est clair et lumineux et qu'il exclut la possibilité d'une mauvaise lecture pour cause de parallaxe. Toutes les lignes d'échelle sont obtenues électroniquement. A la fin de l'article, on décrit l'exécution d'un dispositif de transfert de données pour ordinateur. Le temps maximum requis à cet effet sera d'approximativement 2 msec pour les 38 canaux de fréquence et un canal de reference.

ZUSAMMENFASSUNG

Dieser Artikel beschreibt ein Gerätesystem für automatische Analysen von Schall- und Schwingungsspektren in Echtzeit. Das System unterteilt den Tonfrequenzbereich in Terzen, deren Signalpegel 47 mal in der Sekunde neu auf einer grossen Katodenstrahlröhre in analoger Form abgebildet werden. Analog- und Digitalausgänge erlauben den Anschluß von Analogpegelschreiber bzw. von Digitalgeräten, wie Stanzer, Drucker, Kleinrechner usw.

Der Artikel endet mit der Beschreibung der Digitaldatenübertragung zum Kleinrechner.

Introduction

During the last few years there has been an ever increasing demand for an automatic spectrum analysis system for use in the acoustical and vibrational fields of measurement. First of all such a system should contain a bank of parallel third octave filters with the necessary integrating level detectors capable of handling the RMS value in the Sine, Fast-Random and Slow-Random modes. The standard set of filters should span the range 25 Hz to 20 kHz at least.

The data read out must be analog as well as digital. In the analog mode the CRT display must be bright and clear and free from the possibility of misreading due to parallax phenomena etc., also this mode must be capable of transferring the information to standard type level recorders and other types of external analog instruments.

The digital mode must supply the data in a manner which makes the Real Time Analyzer useful in connection with any type of digital data receiver available to-day (tape puncher, printer, magnetic tape, computer "on line", etc.). Digital technology and system knowledge have in the past years expanded to a level far beyond any estimate made just a few years ago. Still new areas are being opened up to evaluation by digital systems. One of these areas is acoustical and vibrational science. Looking for the reasons for this expansion one must imagine the explosive development within hardware and software technology Hardware technology has developed with the advent of new electronic components, e.g. integrated circuit blocks. Software technology has followed these developments with more useful and flexible methods of using the new hardware components. Sometimes, nowadays, it is hard to define a sharp limit between hardware and software parts. They are both very important for creation of a complete system.

One great advantage of a digital system is the flexibility obtainable. If, for example, in the acustical field one country would like to have noise evaluated after one standard, and a second country after another one, each system could be based on the same hardware, and only the software needs to be changed. Also if a certain standard at a later day is going to be changed, the change in the instrumentation system will only need a change of the programming part. This, naturally, employs the use of an instrumentation computer, but this is also the method to day for evaluating the noise spectrum quickly. Without the computer one may on the other hand still get the data out of the instrumentation system by using level recorders, printers, paper punchers etc. The major asset in digitalization is therefore flexibility and speed in data handling. Slower requirements will still be able to rely on paper recordings and human evaluation. Higher speeds naturally will bring higher system costs, so a compromise between these two will normally be the result.

System Approach

The different requirements and the compromise between cost and speed have therefore demanded a system approach where flexibility is of major importance. The degree of speed will, for example, define the receiving medium, paper- or magnetic-tape, or direct on-line connection to a computer.

In B & K we have found that the systems shown in Fig. 1, meet the above mentioned requirements of speed and flexibility. Fig. 1a shows as an example the system set up, using the Real Time Analyzer connected to a medium speed paper tape puncher. The tape can then at a later time be carried to the computer center which after reading the tape evaluates and reduces the data and then punches out the result on another paper tape, which then in turn may be fed to the tape reader for print out etc. The building blocks used in this system depend only on the wishes and applications for speed in data handling. Fig. 1b shows connection directly on line to any type of computer including special instrumentation computers. In this case the order to transmit data to the computer may also come from the computer, so, for example, it would "ask" for data every 1/2 second.

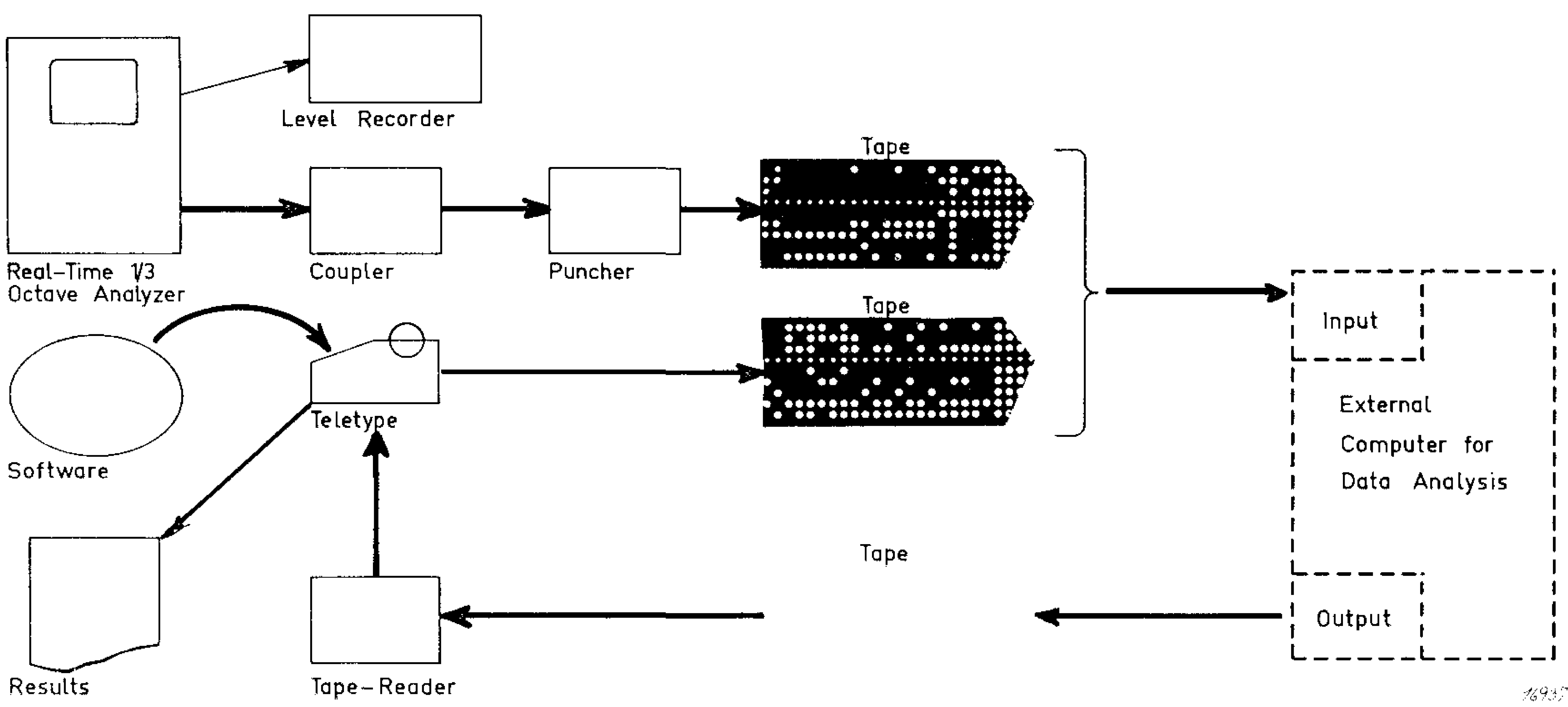

Fig. 1a. Data aquisition system.

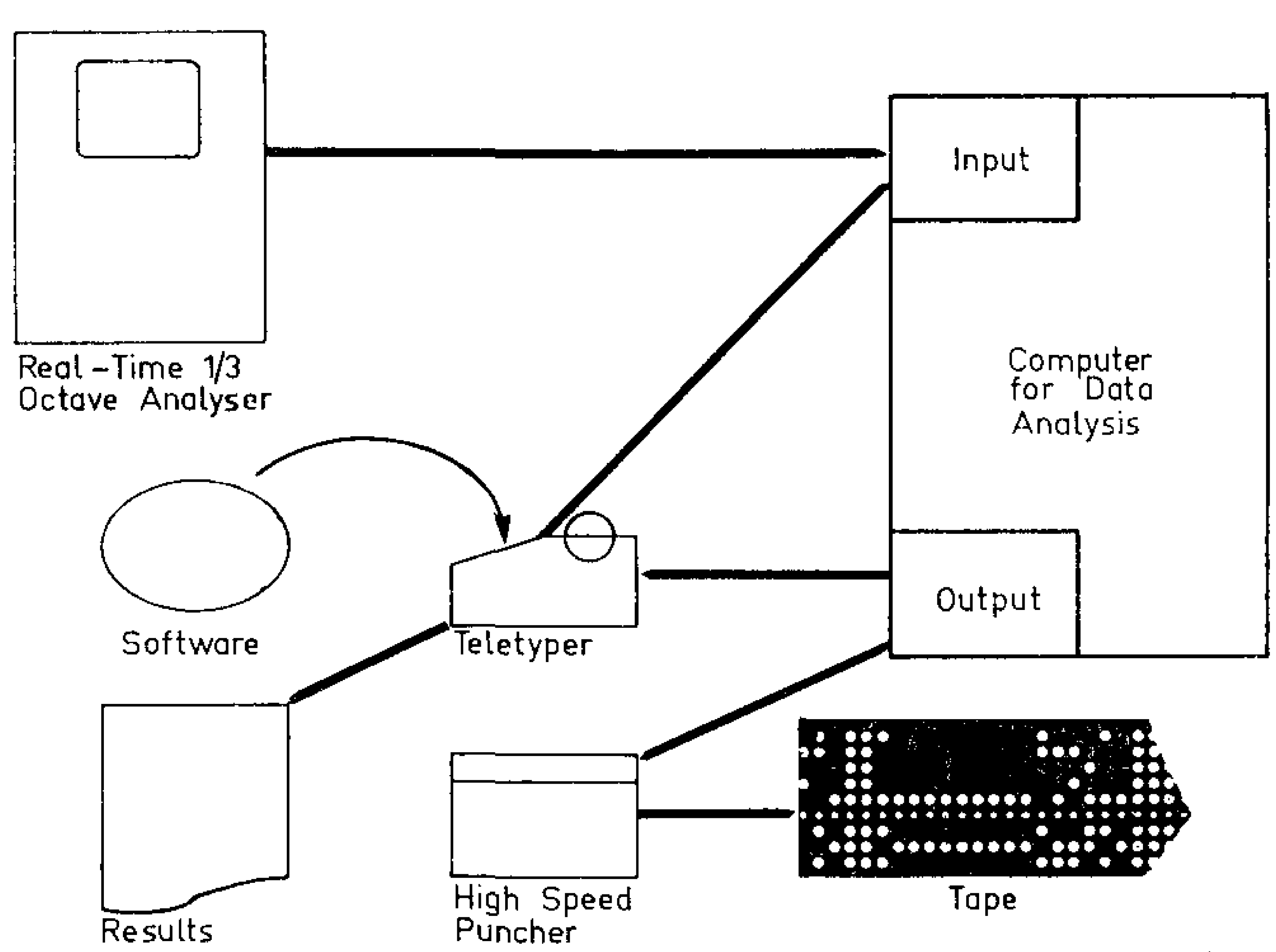

Fig. 1b. On line data reduction system.

The information exchange between Real Time Analyzer and computer will be discussed briefly later so now the Parallelanalyzer itself will be discussed.

Real Time Analyzer

The decision to make an instrumentation system which meets all the above mentioned requirements showed us the necessity of evaluating the system building blocks very carefully.
This resulted in the system 3347 which consists of the Frequency Analyzer Type 2130 and the Control and Display Unit Type 4710.

2130

The 2130 contains basically preamplifier, filters, detectors, logic control and gates as shown on Fig. 2.

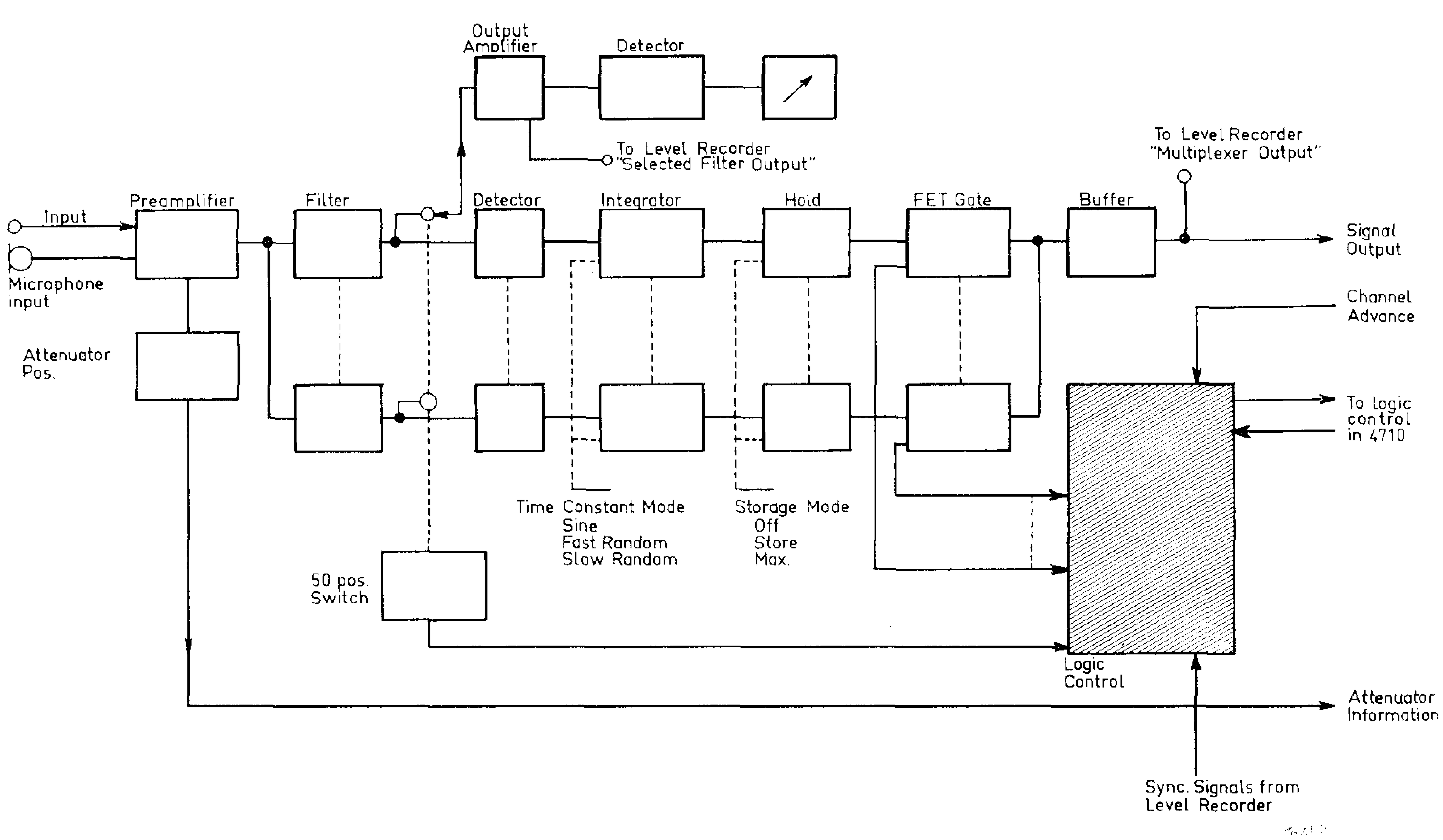

Fig. 2. Frequency Analyzer Type 2130.

The Preamplifier is our standard preamplifier with a direct input, and an input for the condenser microphone. It has an input section attenuator covering a range of 100 dB in 10 dB steps which makes the overall measurement range of the complete system 150 dB including the 50 dB dynamic range "window" of the 4710. The Preamplifier has a frequency range of 10 Hz – 50 kHz ± 0.2 dB and an overload indicator. Information on position of the input section attenuator is fed to the 4710 for use in the binary add section so that the digital display con show the correct sound pressure level in dB, and also this value can be transmitted to the computer.

The filters are the new type 1/3 octave paralleled filters following IEC 225-1966 and ASA S 1.11-1966, class III standards. This means that the response within the passband is within ± 1/4 dB and outside the passband attenuation goes down to 75 dB with an extremely steep slope, well inside the IEC and ASA requirements. The new filters are much better than the B & K filters so far supplied. The center frequencies span from 25–20,000 Hz in the standard equipment, and filters include 10 active and 20 passive units. (The filter set is expandable by extra 3 filters extending the range to 40,000 Hz). Weighting networks are A, B, C (IEC 179-1965) and D for jet noise.

The Detectors are of the RMS type. For signals with crest factors up to 1.4, accuracy is better than ± 0.5 dB for the range 50 to 20 dB and ± 0.85 dB for the 20 dB to 0 dB end of the dynamic range. For crest factors up to 5, the values respectively, will be ± 1 and ± 1.5 dB. It must be remembered that such a signal is an extremely difficult signal to detect correctly. However, for normal random signals smaller crest factors than 5 apply and, therefore, very high accuracy on the RMS Detectors can be achieved.

Time Constants in the integrators are selectable in three modes: Sine, Fast Random and Slow Random.

1. "Sine"	At medium and high frequencies 0.2 sec. it has been found necessary to slightly increase the time constant at the low frequency end to avoid visible ripple.
2. "Fast Random"	0.2 sec. over 2 kHz. Below 2 kHz, following straight line to 20 sec. at 20 Hz.
3. "Slow Random"	20 sec. from 25 Hz to 40 kHz.

These are standard figures but it is possible to accommodate individual requirements.

Hold Features make it possible to work with three different display modes, Store off, Store and Max. Store off just means that the instantaneous RMS value will be displayed. Store means that the RMS level at the instant of store command is stored in the hold circuits, so that read-out an take place. Maximum drift of the store circuits will be 0.2 dB per min. in the range from 10–50 dB. A light indicator is switched on when store or "Max." have been in operation for more than two minutes.
"Max." provides for storage of the highest RMS value reached during a given period of "Max." operation.
During normal read-out sequence to some digital instrumentation, the store circuit is activated at the start of each read-out sequence, whereby the data will be time coincident. This makes it very useful for connection to slow types of read-out devices, such as typewriters, etc. The data in each channel will pertain to the signal present at the same instant of time.
The Gates are controlled by a logic control which gets its advance signals through the 4710 from the computer, puncher, display system, level recorder,

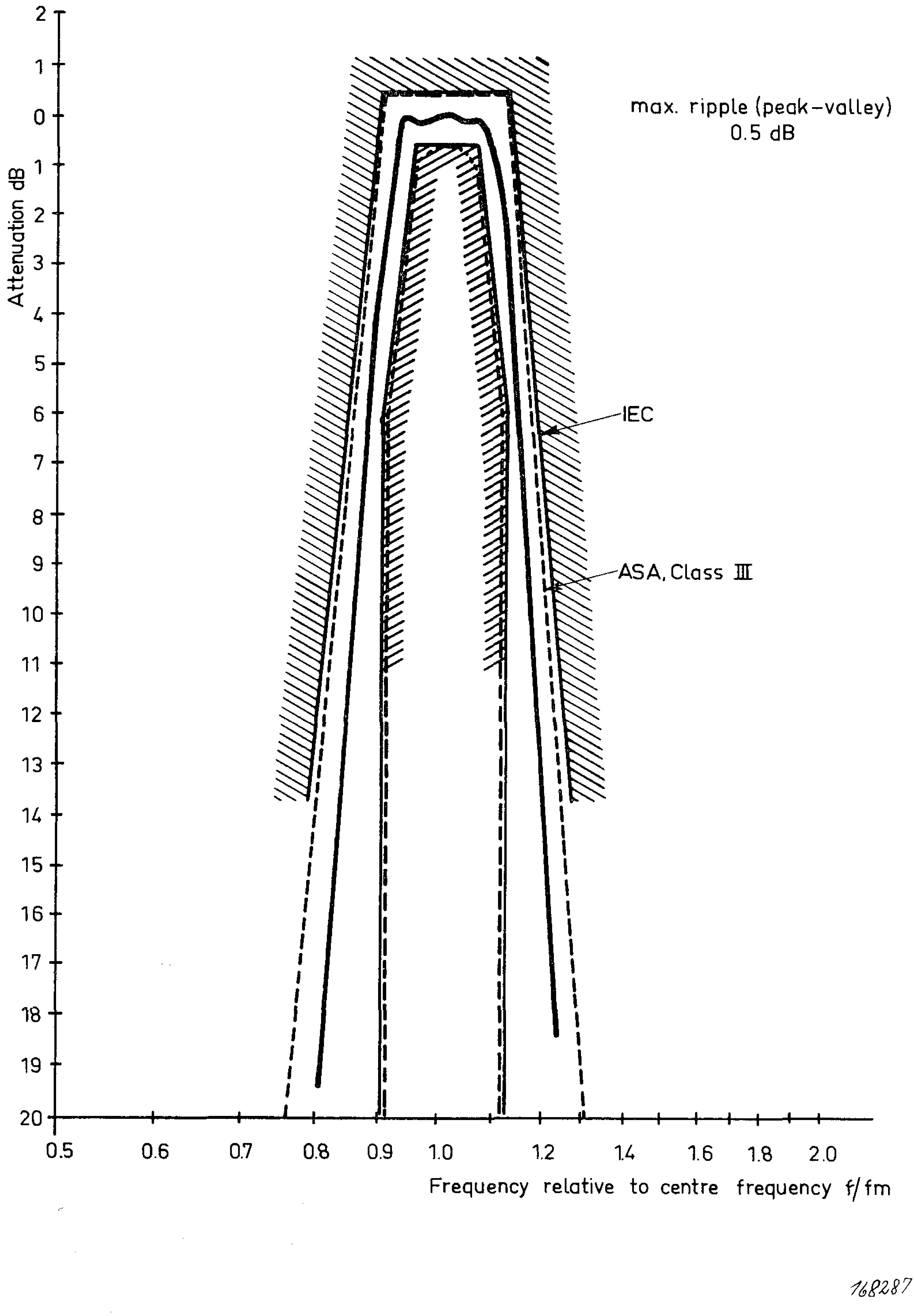

Fig. 3. "Top of typical 1/3 octave filter response.

etc. The 2130 can also be used as an ordinary spectrometer, precision sound level meter, impulse sound level meter and dBN meter. The 50 position switch can select any of the filters or one of the weighting networks, and the appropriate value will be displayed on the meter. The selected channel is given extra light intensity on the tube display.

4710

The 4710 unit is the display and digital unit for the 2130. It contains basically the display system, the logic control unit and the A/D-conversion unit, Fig. 4.

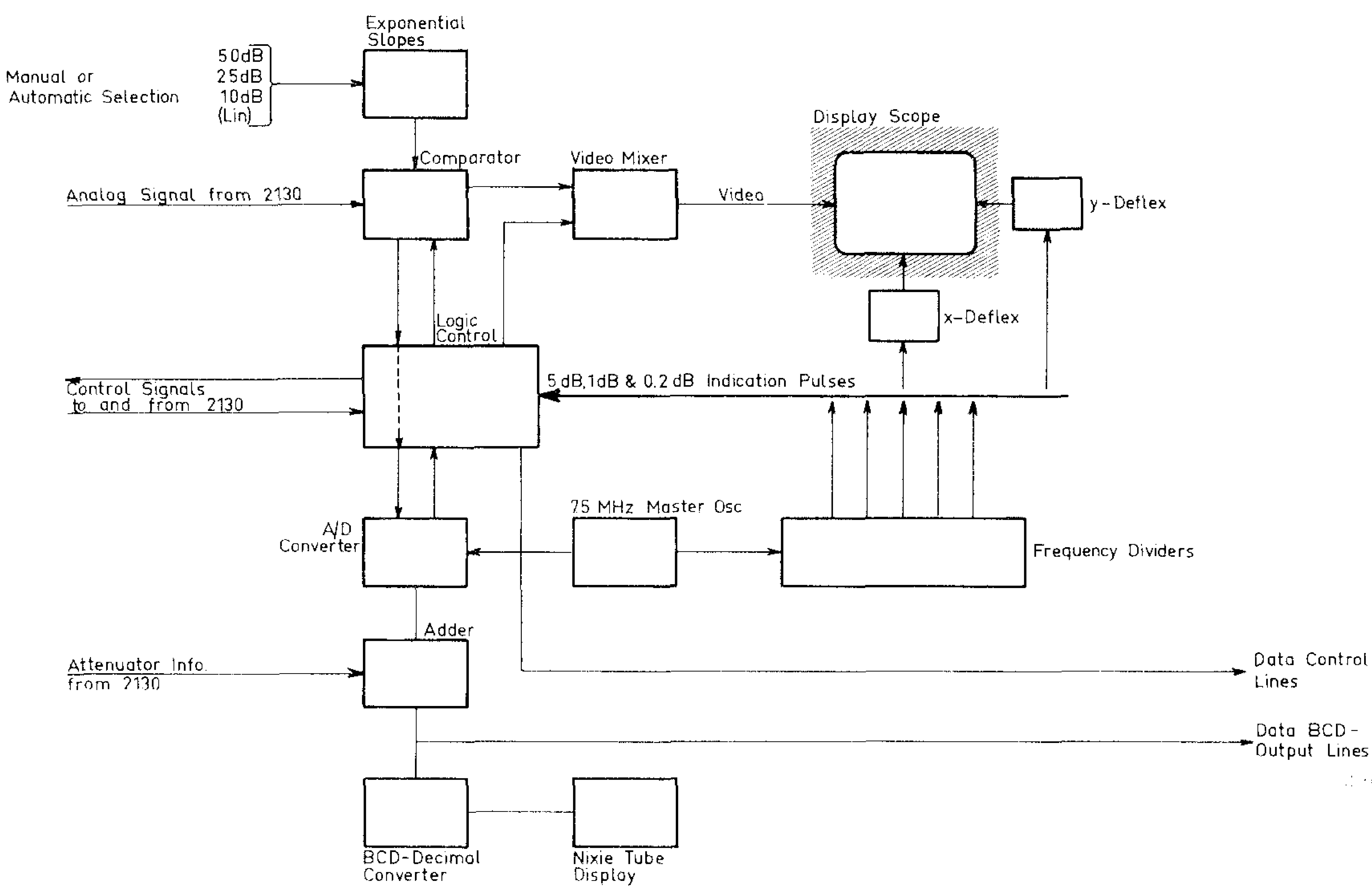

Fig. 4. Control and Display Unit Type 4710.

The master oscillator (7.5 MHz) generates the clock signal used in the system to synchronize display scope, dB indication lines, and A/D converter. Through frequency dividers signals are created to drive the X- and Y-deflection coils on the display scope in perfect synchronisation with the "scan advance" signals etc. from the logic control unit. The analog signal is fed to the comparator which converts linear to logarithmic values so that direct dB indication is obtained. It is also possible to display the spectrum in a linear mode.

The scalelines are processed electronically in the logic control and the video-mixer, so a parallax-free read-out is obtained. This also gives a very positive channel separation and an easy to read vertical scale. On the Y-axis 50, 25, 10 dB and the linear range may be selected.

The analog-digital converter is an integral part of the display unit as the signals required for the display scope are already there. Conversion of each channel takes as little as 53 micro secs. A digital read-out is available for monitoring one of the channels selected by the 50 position switch. In position "Ref. Display" the digital read-out gives the bottom value of the dynamic range in use. Every time we have a read-out to the level recorder, puncher, computer, etc., the read-out will follow the scanner.

Execution of Computer Read-outs

The digital part of the instrument uses exclusively integrated circuit of the modern TTL-type with delay times in the 10 nanosec.-range. This means that we obtain a very high level of reliability which is of great importance in a complex system like this where many functions are concentrated in one instrument.

The digital output terminals are shown on a sketch (Fig. 5). The complete output termination contains basically 16 data lines and 4 data control lines. The 16 data lines are based in groups of four lines representing each digit. The data lines are coded in the standard BCD-code and weighting orders are 8–4–2–1.

There are 4 data control lines which control the process of read-out as follows: (Fig. 5).

a. The "Data request" line transmits a "1" signal from the computer or external equipment to the Analyzer, asking for the start of a read-out sequence. The leading edge of this signal causes:

1. The stopping of the display mode.
2. The resetting of the multiplexer in 2130 to channel number 0 (ref. level).
3. Automatic selection of the 50 dB range.
4. Activation of store circuit as mentioned earlier.
5. The start of the A/D-conversion, which takes approximately 50 micro sec.

b. When data on the 16 data lines is ready for transmission to external equipment, the "data ready" signal from the Analyzer becomes "1".

c. As soon as the external equipment has accepted the data information (punching of holes is finished or computer has accepted the data), the external equipment sends a "1" signal on the "Data received" line to the Analyzer. The Analyzer will use the leading edge of this signal to 1) shut down to the data ready linie, 2) to create a "scan advance" signal and 3) move the multiplex one position to the next channel and to start a new conversion.

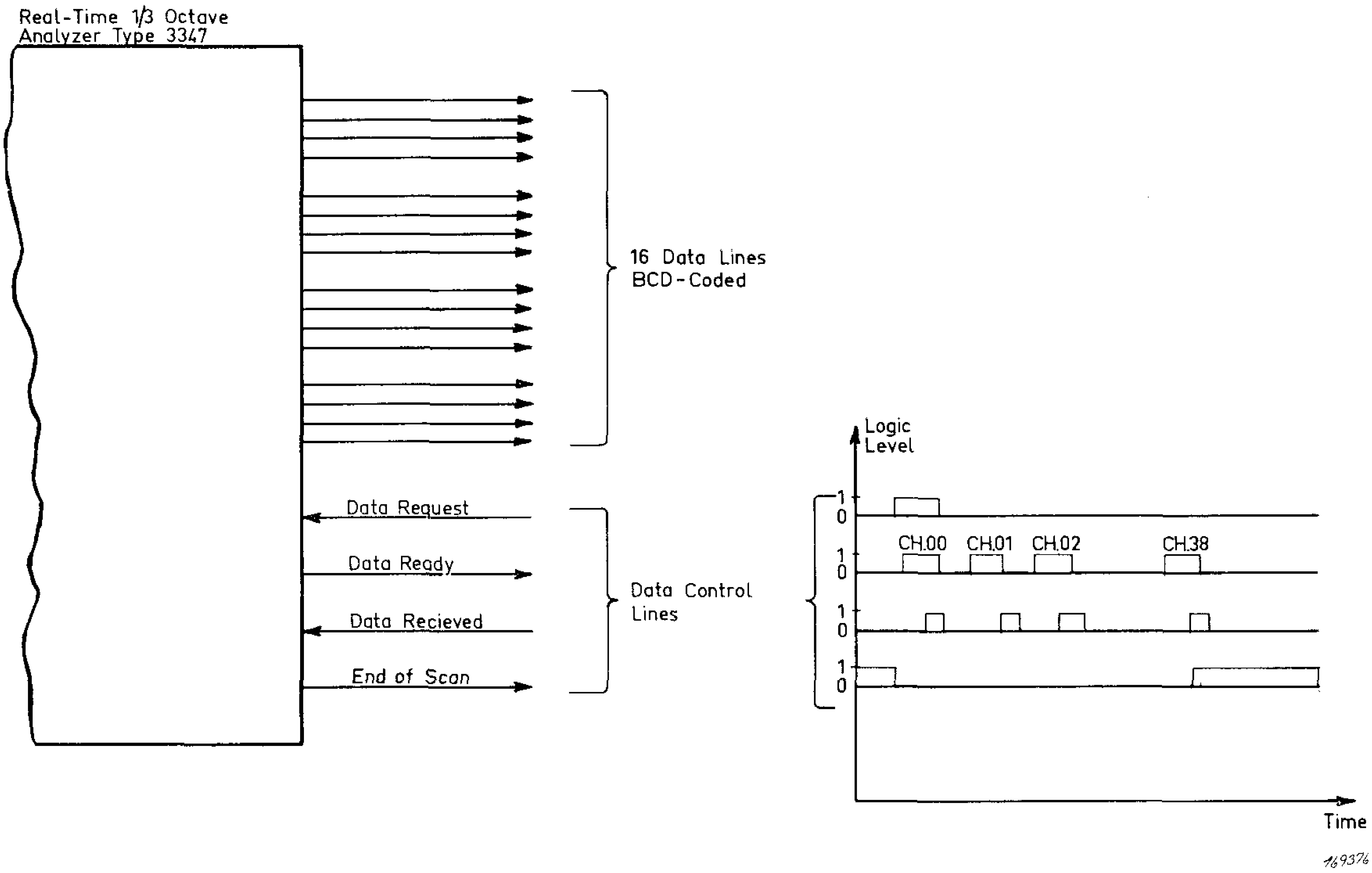

Fig. 5. Information transfer.

The process continues like this, "data ready" and "data received" signals alternately being sent untill all channels have been scanned.
When the Parallelanalyzer has received the "data received" signal from the external equipment after the reading of the last channel (ch. 38) the Parallel-analyzer will answer by raising the "End of Scan" signal to "1", and keep it at "1" until another "Data request" signal is received. At the same time the CRT-display mode will re-appear. The minimum time required for reading out a complete scan of 39 (38) channels is approximately 2 msec.

Conclusion

We believe that we have made a flexible system which easily matches almost every type of external equipment available to-day. It looks as though the main applications are in real time analysis of aircraft noise, speech and other kinds of noise and vibration signals with changing spectra. The ultimate flexibility of the system depends on the type of equipment that one can afford to couple with it.

Field Calibration of Accelerometers

by

Frederik Zeitz Floor

ABSTRACT

The paper outlines the demands to field calibration methods for accelerometers. It also describes a small calibration-shaker which gives an overall accuracy of 2 % using the comparison method. This accuracy can be improved to 0.5 % by individual calibration. An accuracy of 5 % can be obtained by the chatter method.

SOMMAIRE

L'article note les exigences de méthodes d'étalonnage en chantier d'accéléromètres. Il décrit également un petit excitateur de vibrations d'étalonnage qui donne une précision globale de 2 % en faisant appel à la méthode de comparaison. Cette précision est portée à 0,5 % par étalonnage individual. Une précision de 5 % peut être obtenue par la méthode du ballottement.

ZUSAMMENFASSUNG

Dieser Aufsatz umreißt die Ansprüche an Feldkalibriermethoden für Accelerometer. Er beschreibt auch einen kleinen Kalibrierschwingtisch, der bei Anwendung der Vergleichsmethode eine Gesamtgenauigkeit auf 2 % ermöglicht. Diese Genauigkeit kann bis auf 0,5 % verbessert werden, wenn der Schwingtisch individuell kalibriert wird. Nach der Prallmethode ist eine Genauigkeit auf 5 % möglich.

Accurate calibration of accelerometers has been and will always be a laborate procedure which can not easily be applied in the field.

The most commonly used methods are described in the two well-known standards ASA S2.2-1959 and DIN 45666. Several methods are described in the ASA standard for absolute calibration, but today the methods most commonly used are:

The Reciprocity Method,
The Optical Method,
The Interferometer Method.

When evaluating a method for field calibration it must be reasonable to choose a method based upon the reciprocity calibration as the optical and interferometer methods are only useful at rather low frequences, unless extremely elaborate equipment is used.

A third method (not absolute) mentioned in ISA-RP 37.2-1964 (Recommended Test of Piezo-Electric Acceleration Transducers for Aero-Space Testing) is the chatter mehod. This method is described as the simplest to use and the most dependable for reasonable accuracy.

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*) Paper presented at the 6th International Congress on Acoustics, Tokyo, Japan 21 –28 August 1968.

For laboratory calibration the reciprocity calibration would be the preferred method, while the optical methods are very useful for monitoring large scale production.

The reciprocity calibration is today usually carried out with electrodynamic shakers having two moving coils one of which is used as the one of two reversible transducers being reciprocity calibrated. The other being a stable, reversible piezo-electric accelerometer. The second coil in the shaker is used to drive the two reversible transducers for comparison of their sensitivity.

Comparison by means of accelerometer standards demands as well a good reversible accelerometer. These are today made by most accelerometer manufacturers.

An accelerometer suitable for use as primary standard should have a well aged stable piezo-electric element with a well machined mounting surface. Low transverse sensitivity, less than 3 % is adequate, and very low base strain sensitivity. A type with high voltage sensitivity and high charge sensitivity should normally be preferred.

The demands to a good field calibrator must first of all be reliability, handiness, portability, and it must be possible to use it with traceable standards and for absolute calibration of secondary standards.

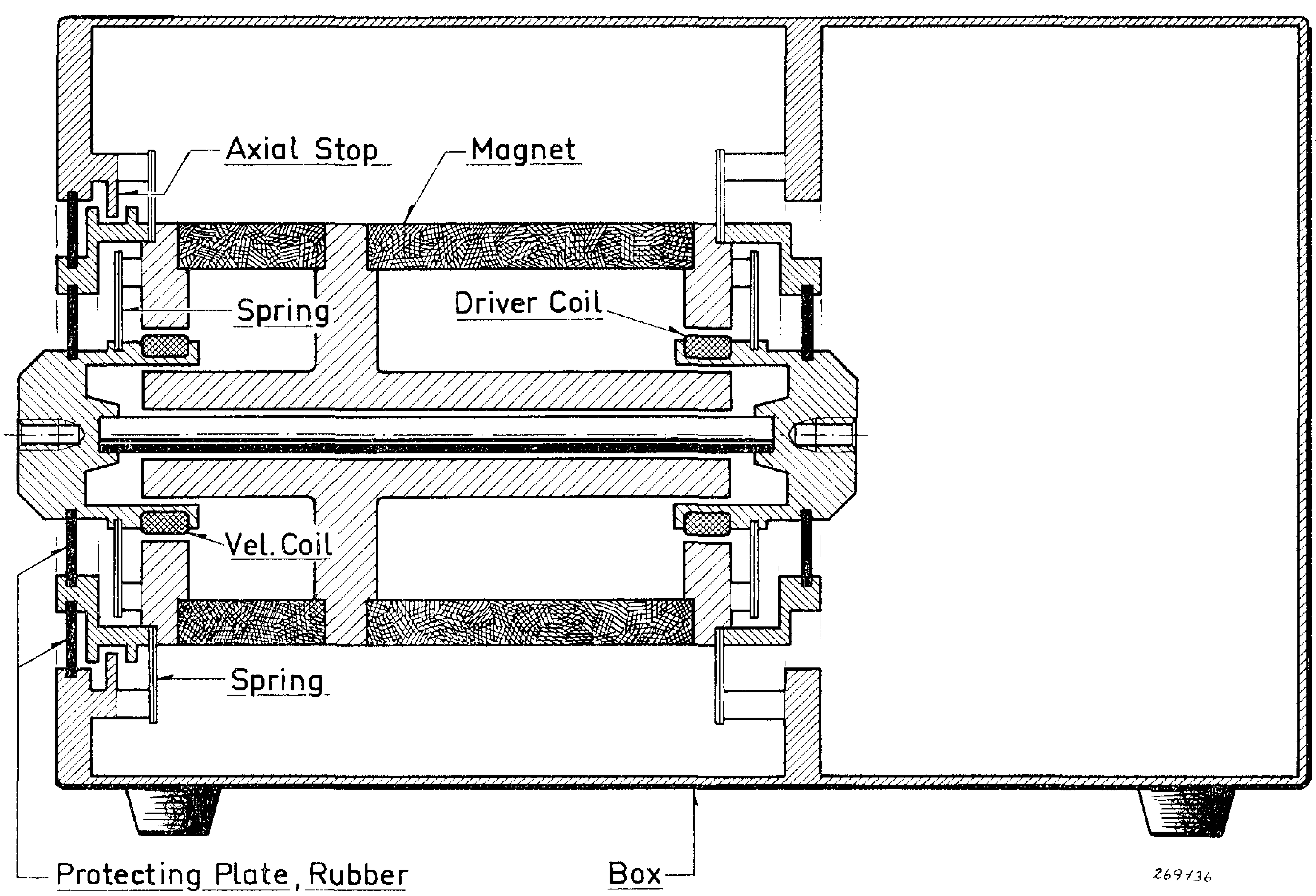

Fig. 1. Schematic drawing of small calibration-shaker.

In order to fulfil these demands the calibrator must contain a built-in generator with preferred standard frequency. ASA S2.2.-1959 demands 40–100 Hz, DIN 45666 states $\omega = 500 = 79.6$ Hz.
The frequency 79.6 Hz should be chosen as it fulfils both standards, and $\omega = 500$ gives easy conversion to acceleration and displacement,

$$\text{f. inst. } V = 10 \text{ mm/sec}, a = 5 \text{ m/sec}^2, d = 0.02 \text{ mm}.$$

Furthermore it is demanded that the angle between the axis of movement and the transducer sensitivity axis is smaller than 5 degrees, and distortion should be less than 5 % (3 % in ISA RP 37.2).
In Fig. 1 is shown a schematic drawing of a small calibration-shaker with two moving coils, one used as driving coil, the other as velocity coil. Reciprocity calibration was carried out with ten equal masses of 50 gr ± 1 %.
The voltage across the precision resistor in series with the driving coil was kept constant and the output voltage from the accelerometer recorded. Frequency and distortion was checked through all measurements. The result is given below.

Frequency = 79.6 $E_{Drive} = 500$ mV

$E_{acc.}$ mV	$G = \frac{E_{Drive}}{E_{acc.}}$	$G_n - G_0$	$J = \frac{W_n}{G_n - G_0}$
136	$G_0 = 3.68$		
65.5	$G_{50} = 7.64$	3.96	12.6
42.5	$G_{100} = 11.77$	8.09	12.4
31.6	$G_{150} = 15.82$	12.14	12.35
25.2	$G_{20D} = 19.85$	16.17	12.37
21.1	$G_{250} = 23.7$	20.02	12.39
17.9	$G_{300} = 27.9$	24.22	12.39
15.8	$G_{350} = 31.7$	28.02	12.46
14.1	$G_{400} = 35.65$	31.97	12.5
12.8	$G_{450} = 40.7$	37.02	12.1
10.7	$G_{500} = 46.7$	43.02	11.6

With the second driving coil the first driving coil and accelerometer was vibrated at the same frequency, 79.6 Hz, and voltage ratio found.

$$\text{The voltage ratio} = \frac{E_{acc}}{E_{Drive}} = \frac{30}{20.8} = 1.44.$$

The two sensitivities were found:

$$S_{acc} = 124 \times \frac{J}{f} \times \frac{E_{acc}}{E_{Drive}} = 58.6 \text{ mV/m/sec}^2$$

$$S_{vel.} = 124 \times \frac{J}{f} \times \frac{E_{Drive}}{E_{acc}} = 58.6 \text{ mV/m/sec}$$

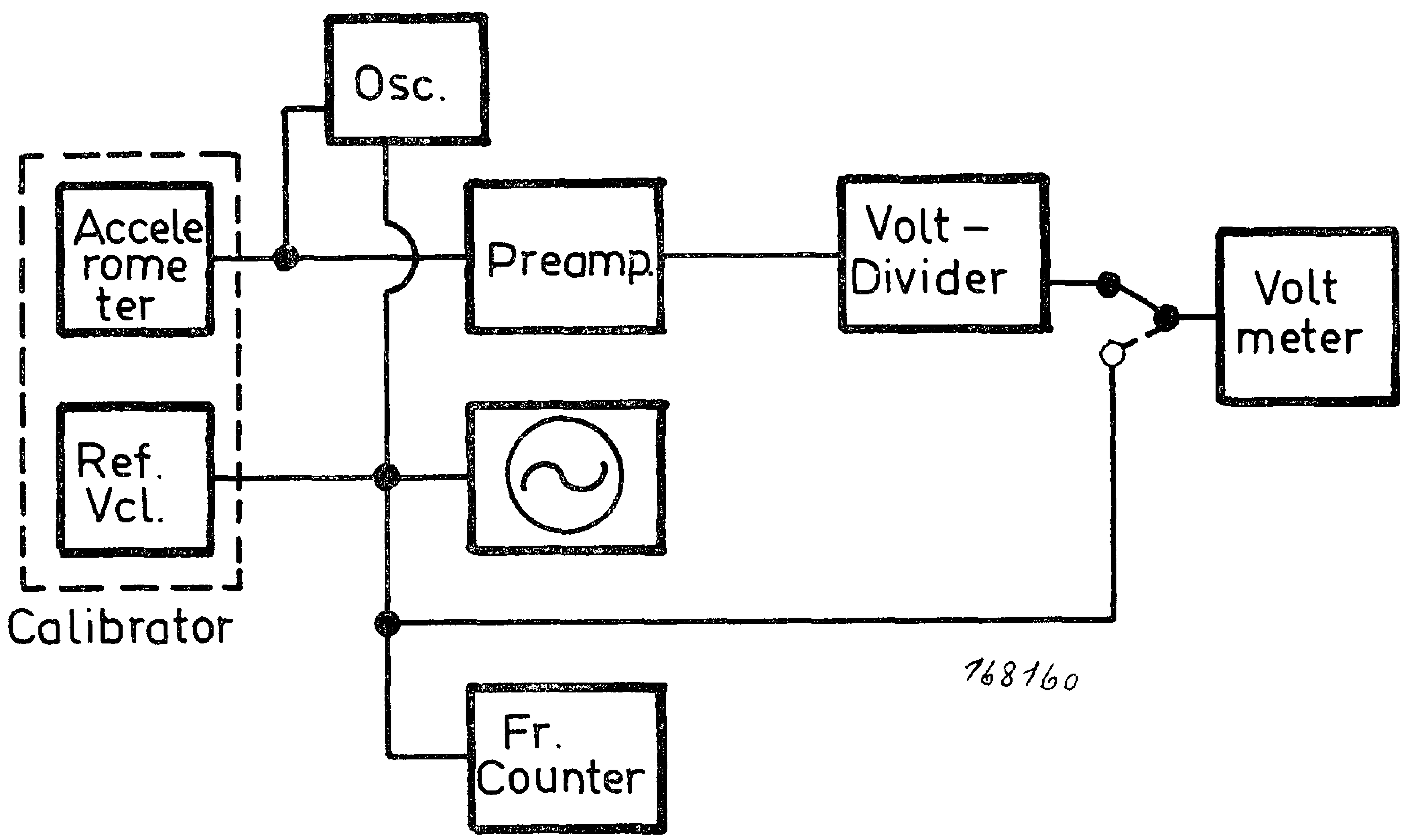

Fig. 2. Block diagram of calibration set-up.

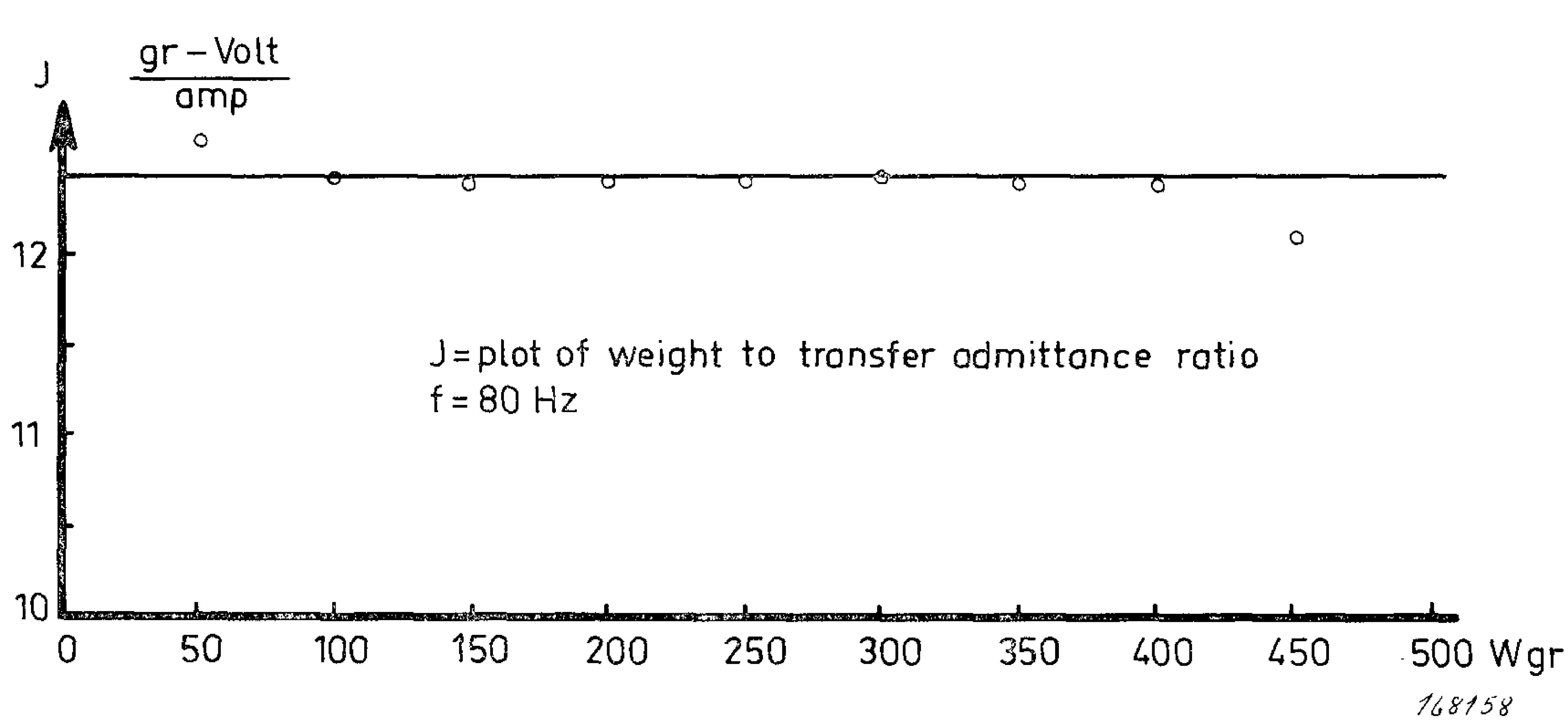

Fig. 3. Weight to transfer admittance of calibrator.

In the calibrator a meter for indication of a given level, e.g. 1 g, can be built in. By using the velocity coil the comparison method gets extremely simple to carry out. The overall accuracy was found to be as good as 2 % by this method.
By individual calibration the accuracy can be improved to 0.5 % as well as one can extend the frequency range considerably.
The calibrator can easily be used for the chatter method as well. With an Oscilloscope as indicator an accuracy of 5 % was achieved.

The synchronization of a B & K Level Recorder Type 2305 for spatial plotting

by

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ABSTRACT

A method is described for synchronizing a B & K Level Recorder Type 2305 for automatic plotting of parameters which vary in 2 dimensions. The method can be extended to 3-dimensional parameters, and is suitable for spatial plotting of the sound intensity produced by a sound source.

The synchronizing mechanism is fully described and some sample results and suggestions for different applications are given.

SOMMAIRE

Une méthode est décrite pour synchroniser un enregistreur B & K type 2305 en vue du relevé automatique de paramètres qui variant dans deux dimensions. La méthode peut être étendue à des paramètres de 3 dimensions et convient pour le relevé spatial de l'intensité sonore produite par une source sonore.

Le mécanisme de synchronisation est entièrement décrit et quelques échantillons de résultats comme des suggestions pour différentes applications sont données.

ZUSAMMENFASSUNG

Dieser Artikel beschreibt eine Methode zur Synchronisierung eines B & K-Pegelschreibers Typ 2305 für die automatische Aufzeichnung von Parametern, die in zwei Dimensionen variieren. Diese Methode kann auf Parameter, welche in drei Dimensionen veränderlich sind, ausgedehnt werden. Sie ist für die räumliche Aufzeichnung der von einer Schallquelle erzeugten Schallintensität geeignet.

Der Mechanismus zur Synchronisierung wird ausführlich beschrieben und einige erzielte Ergebnisse sowie Vorschläge für verschiedene Anwendungen werden angegeben.

Introduction

In normal measuring practice, a voltage can be recorded as a function of time using the B & K Level Recorder Type 2305. The paper feed gives a time axis as abscissa, and the voltage is recorded on a linear or logarithmic scale as ordinate.

There are a large number of measurements, however, where the voltage is to be recorded not as a function of time but as a function of some other parameter. In these cases, the Level Recorder can also be used when the given parameter can be made a known function of time, and the measuring result of the given parameter is synchronized with the time axis of the recording. If, for instance, the frequency response of an electrical 4-pole network is to be plotted, the frequency is scanned in time in a predetermined manner, and as the Recording paper moves the voltage will be plotted as a function of frequency.

The coupling of the frequency scan and paper scan is utilized in the B & K Automatic Frequency Response Recorder Type 3308 and in the Audio Frequency Spectrum Recorder Type 3315. The Turntable Type 3921 translates polar angle variations into time variations.
It is often required, in some measurements, to plot the spatial distribution of a parameter. If the parameter to be measured can be transformed into a voltage, the above mentioned method can be used.
To solve such a measuring problem, therefore, with the Level Recorder Type 2305, two conditions must be fulfilled:

1. Transformation of the quantity to be measured into a voltage variation.
2. Synchronization of a spatial sampling process with the time change either continuously or to a predetermined programme.

The first condition can be relatively easily fulfilled, since there are many different types of transducer available and electroacoustic transducers especially are well developed. The second condition was realized in the Author's Institute for a particular measurement of the fine-structure of the sound field produced by various acoustic radiators or combinations of radiators (1, 2).
Three dimensional movements are in principle possible in space, but since one axis of the Level Recorder is reserved for the voltage, only one dimensional movement can be synchronized with the paper feed. Movements in the two other dimensions must therefore be made step by step, with the synchronized paper feed and one-dimensional movements repeated between steps. With certain additions to the automatic mechanism of Brüel & Kjær instruments, the movements in the second or third coordinates can be automatically (i.e. without further contact by hand) recorded on the Level Recorder.

Construction and Operating Principle of the Automatic Measuring Arrangement

To sample and transduce the sound field of a sound radiator or radiator combination, a B & K measuring microphone is used, which is movable along a fixed path. The radiator is mounted by means of a stand onto a Turntable Type 3921. (Fig. 1).
The measurement procedure is as follows:
To begin with the microphone is placed near the radiator, so that the axis of the radiator is in line with the line of movement of the microphone. A start signal initiates the measuring tone in the radiator and the movement of the microphone, and starts the Level Recorder. During the movement of the microphone, complete synchronization between the Level Recorder and microphone drive motor must be ensured. After the first 10 cm of the microphone movement, and after every further 10 cm section of the movement, a marker is put onto the recording paper. When the microphone reaches an extreme position of its movement, the measurement tone is switched off, the microphone and Level Recorder stop and the Turntable begins to rotate. During this rotation the measurement is suspended. When the Turntable reaches a

certain pre-determined point, it stops rotating and the measurement recommences, but with the microphone moving in the opposite direction. Each 10 cm section is again marked, and a second curve is thus produced.

The measurement continues in this way as long as required, and then stops automatically, awaiting a new start signal. The third space coordinate can at this point be changed, or another parameter changed, e.g. the measuring frequency. These adjustments are effected manually. It is expedient also at this point to check or calibrate the system, since the measurements are fairly time consuming.

Returning now to the automatic synchronization mechanism of the Level Recorder, the following modifications were made:

By means of drive shaft I, electrical coupling to the microphone movement was produced, with a feedback system which gave excellent synchronization between the microphone and paper drive motors.

Contacts are mounted under the microphone track and a sliding contact closes and opens a circuit as the microphone moves. Similar contacts on the stationary part of the Turntable are closed and opened by a sliding contact on the rotating part.

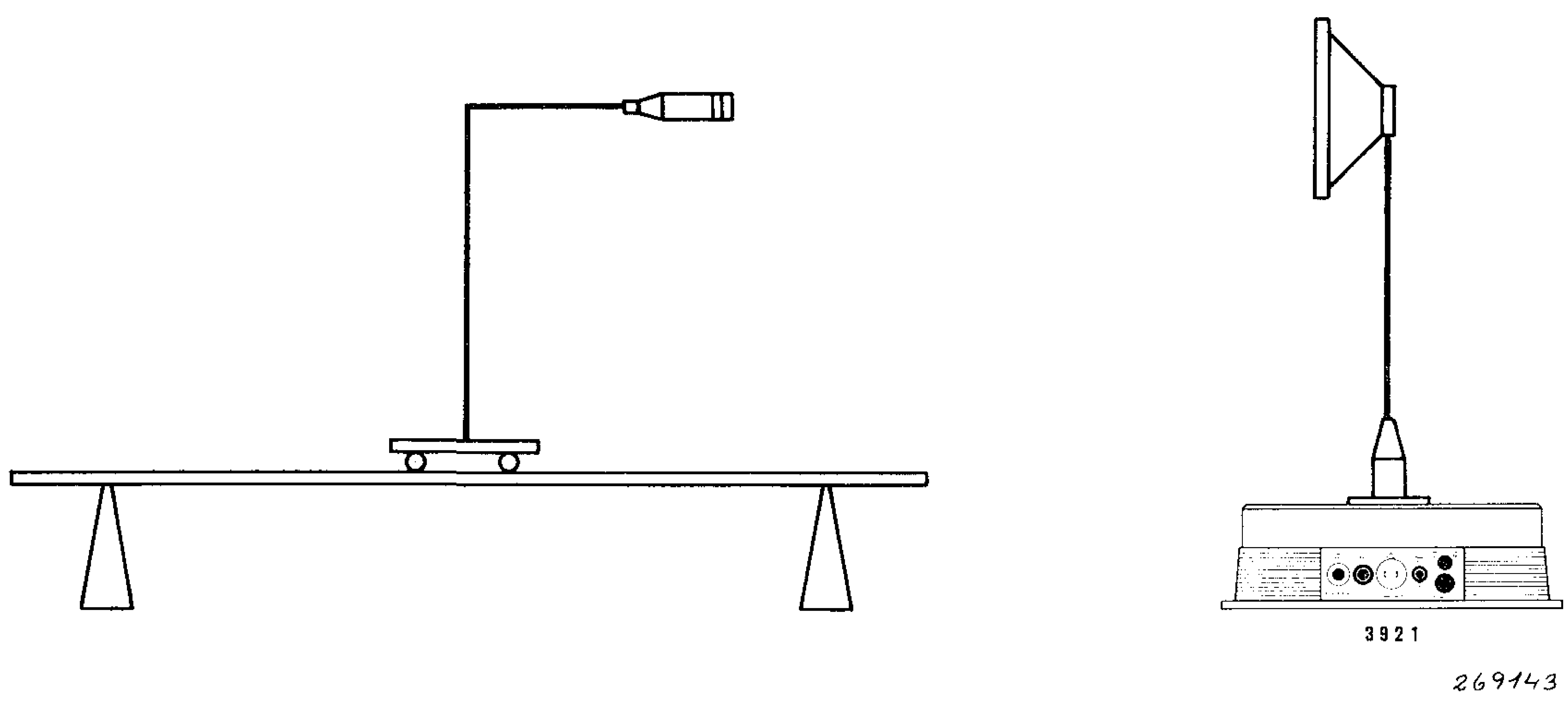

Fig. 1. Measuring set up of radiator and microphone.

The control system uses relays as control elements (Fig. 2) and during the movement of the microphone the slider shorts between the contacts on the contact rail 1 and operate relay 7 which in turn operates the marker on the Level Recorder. At both ends of the microphone path is a relay (relays 1 and 3). If the microphone moves for instance to the extreme left and reaches

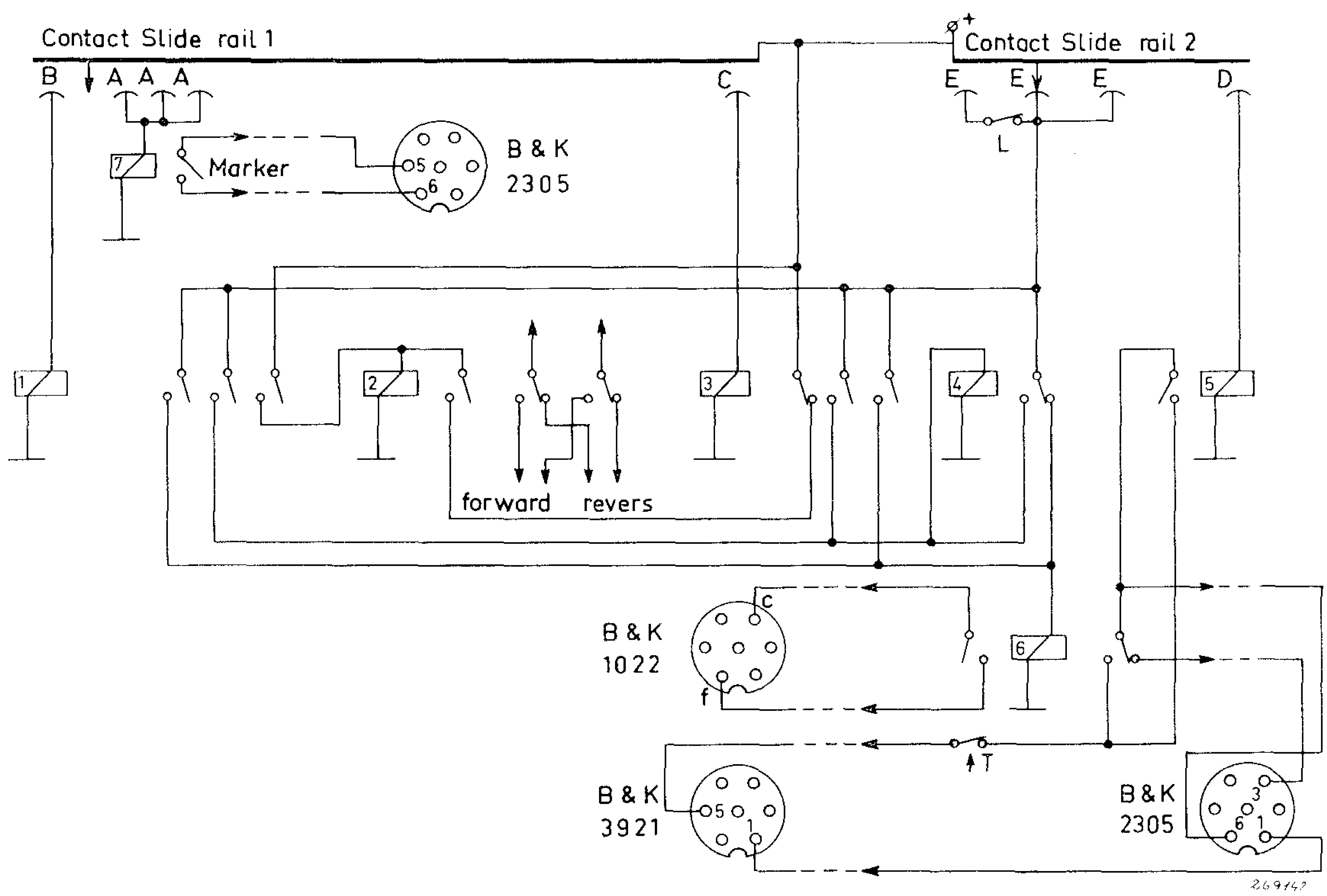

Fig. 2. Control system.

contact B, relay 1 closes and operates relay 2, which reverses the microphone drive motor. Relay 2 also operates a hold circuit through the normally closed contacts of relay 3, so that the same motor direction is maintained until the microphone reaches the other (right-hand) end of the path. Relay 1 connects the hold circuit of relay 6 which provides an OR-function; + 24 V is supplied either to the Turntable or Level Recorder so that only one of them operates at a time (either the Turntable rotates or the paper feed is in operation). Before the microphone slider reaches contact B, relay 6 is operated through the normally closed contacts of relay 4, and the Turntable is still. After the actuation of relay 1, instead of the normal contact of relay 4 (which is in any case actuated by relay 1) keeping relay 6 operated, a working contact of relay 1 takes over, so that the Level Recorder and microphone are still moving, and the Turntable is stationary. After a short time, however, the movement of the microphone in the reverse direction brings the slider and contact B apart and relay 1 is no longer actuated. The hold circuit of relay 2 maintains the same microphone motor direction, but relay 6 goes off with relay 1, so that the microphone stops and the Turntable begins to rotate. The movement of the Turntable causes its sliding contact to leave contact E so that relay 4 is switched out. When the slider reaches the next contact E, relay 6 is again actuated, the Turntable stops and the microphone movement restarts.

At the right-hand end of the microphone path the operation is quite similar. After the Turntable has operated at all the preselected positions, its sliding contact reaches contact D, which operates relay 5 and only stops the Turntable without starting the Level Recorder. Via relay 6, the measuring tone is also switched off during the periods when the microphone is stationary. As a further addition, there is a push-button (T) to start the Turntable manually whenever desired. The slide rail 2 is provided with a switch L which allows the 0° position contact to be separated from the others so that the other positions of the Turntable are omitted.
The operation of the system starts with setting up in a principal direction of the radiator, usually the 0° direction, and therefore with the 0° "E" contact switched out. After setting up, button T is pressed and the Turntable rotates to D. If everything is ready for measuring, L is closed to connect all the "E" contacts and T pressed again, and the Turntable stops itself at the first "E" contact. The microphone movement must be started by switching the "Paper Drive" on the Level Recorder to "Start" (the Recorder should be in the "Single Chart" position, and the 1 : 10 gear should be disengaged). The operation then proceeds automatically. When the first curve has been recorded, the second one is recorded at the next angular setting, but in the reverse direction. It is possible, though more time consuming for measurements, to modify the set-up for recording always in the same direction.

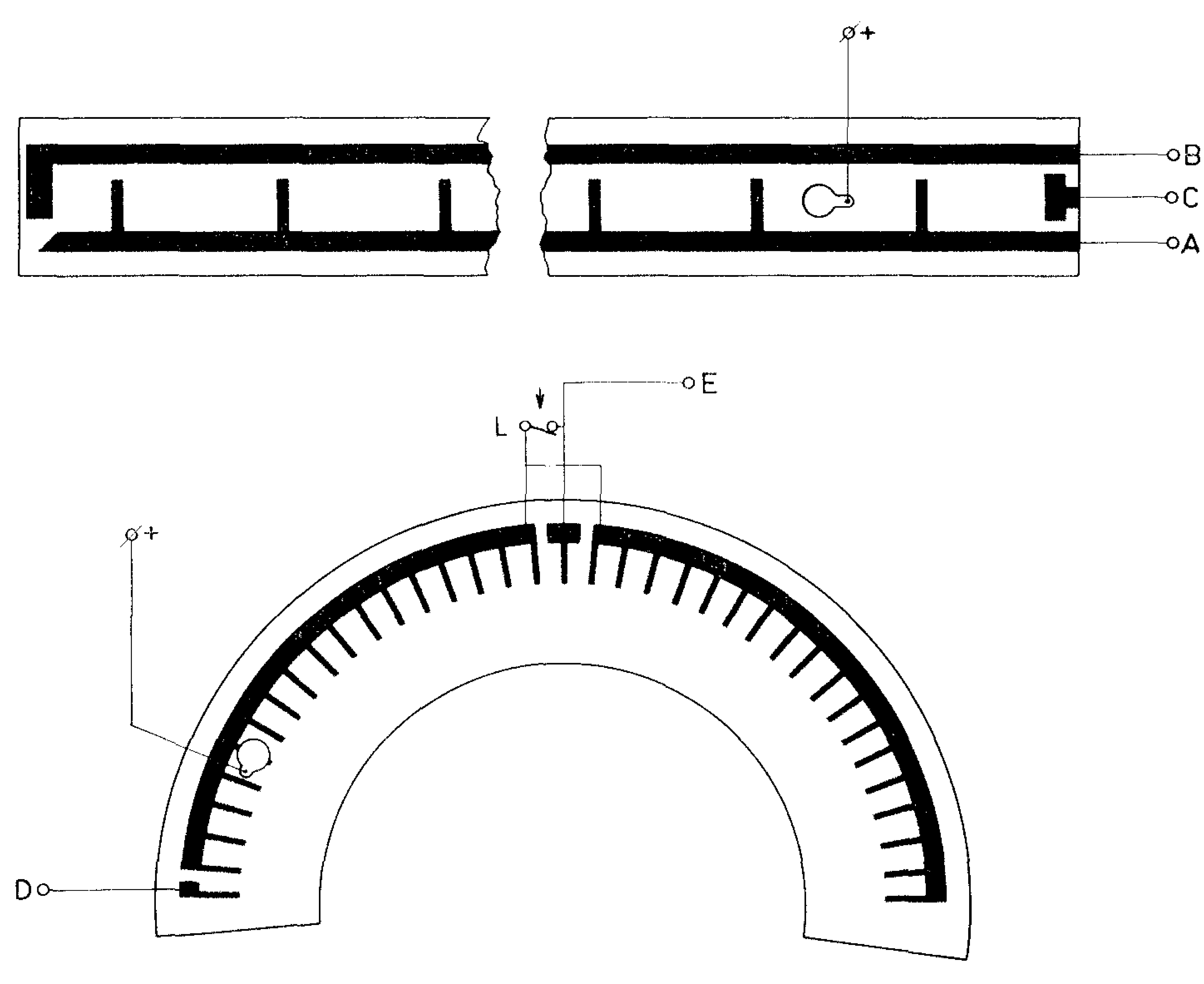

Fig. 3. The arrangement of the contacts on the microphone track (above) and the turntable.

Applications

In our particular measurements, a point source was mounted in an anechoic chamber, and the microphone began its movement 5 cm away. The microphone track was 95 cm long and the microphone moved at 10 mm/sec, with a paper speed of 1 mm/sec. This gave a scanning time of around 2 min per angular setting. The angular positions were set at every 5°, so that 37 curves were recorded for a half-revolution, requiring about 1.25 hours. It should be mentioned that these figures apply for a two-dimensional sampling; a three-dimensional measurement needs longer than a normal working day to complete.

Finally, some of the recorded curves are shown. Fig. 4 shows the sound pressure variation at 19 kHz along the axis of a circular radiator of 300 mm diameter. The dotted line indicates the 1/r law dependence, and it can be seen that there are deviations from this law, especially at high frequencies, where reflections from the walls of the chamber become noticeable. With the aid of the marks on the paper (each 10 cm of path) the periodicity can be estimated.

Fig. 5 shows a detail from the sampled sound field of a point-source, in directions 20° and 25° from a reference axis. The change of angle takes place at the vertical line, which is drawn when the source switches off.

This scanning system can also be used with success in fields other than acoustics, such as microwave measurements, isotope research, etc. New

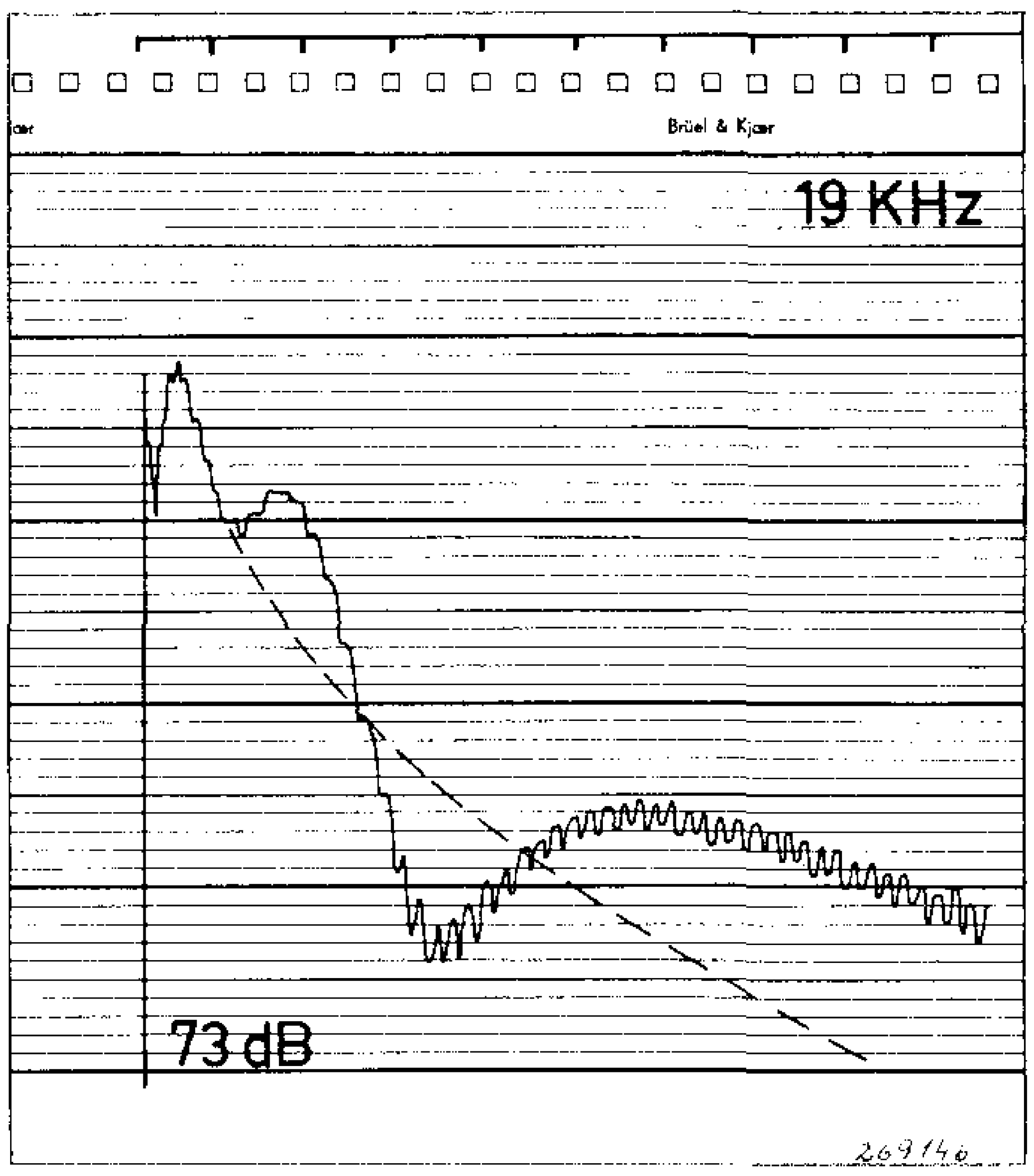

Fig. 4. Sound pressure variation as a function of distance in the axis of a 300 mm radiator.

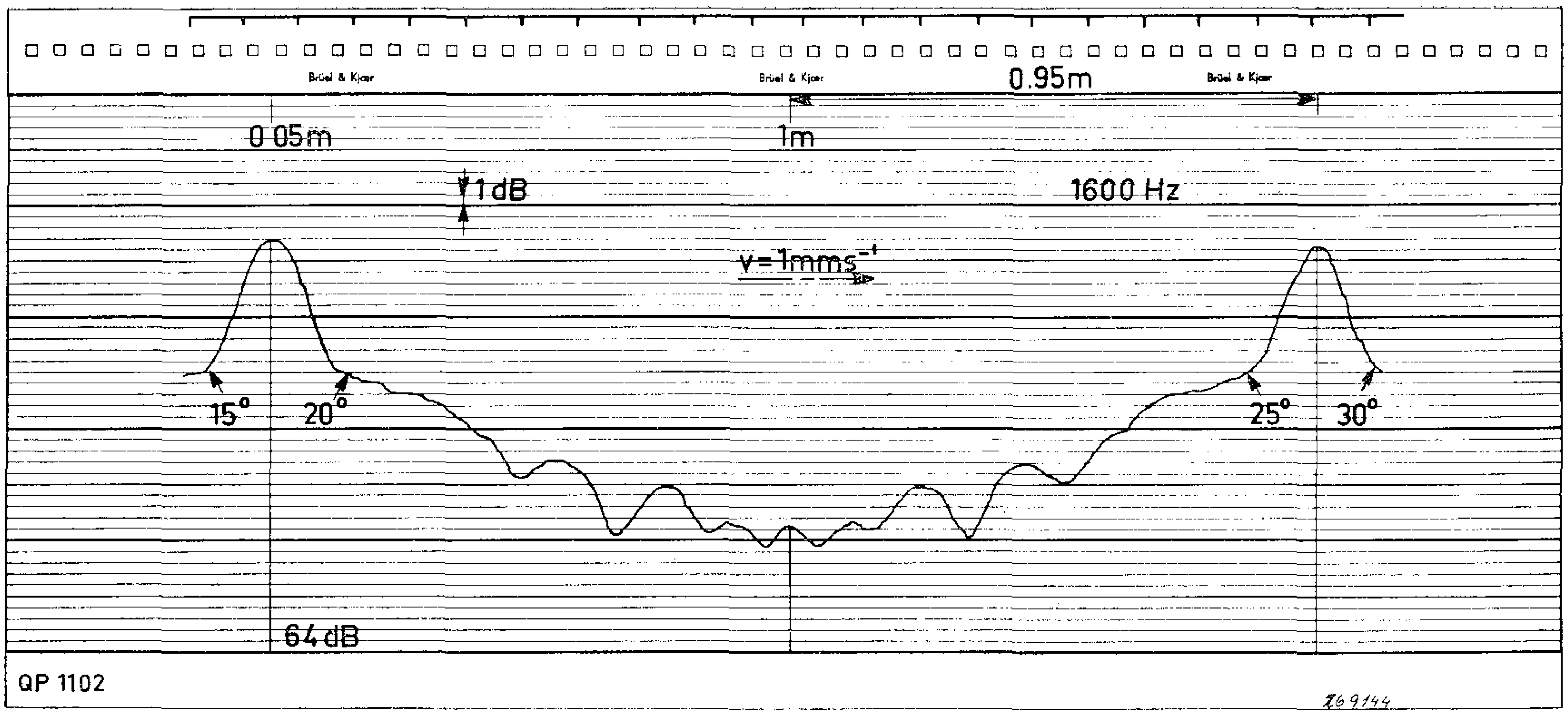

Fig. 5. Sound pressure variation as functions of distance at 20° and at 25° from axis of point source.

applications occur day by day in the authors own institute. In general, all series measurements where a position dependence is found can be made in this way. (Sound field analysis in the audio or ultrasonic range, model measurements, vibration analysis, measurements in Kundt's tube, dynamic scanning of a loudspeaker diaphragm, etc.).

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1. ILLÉNYI, A.: Untersuchungen in der Achse Kreissymmetricher Strahler. Proc. 5e Congrés Int. d'Acoustique, K 52.

2. ILLÉNYI, A., RADNAI, J.: Ein automatisches Schallfeldabtastsystem. IV Acoustic Conf., Budapest, 1967.

Brief Communications

The intention of this section in the B & K Technical Reviews is to cover more practical aspects of the use of Brüel & Kjær instruments. It is meant to be an "open forum" for communication between the readers of the Review and our development and application laboratories. We therefore invite you to contribute to this communication whenever you have solved a measurement problem that you think may be of general interest to users of B & K equipment. The only restriction to contributions is that they should be as short as possible and preferably no longer than 3 typewritten pages (A 4).

An Acoustic Measuring Method to Reveal Cracks in Cast Iron Workpieces Having Rotational Symmetry

by

R. Kühl - G. Wennigstedt - E. Hahn)*

The experimental set up described in the following, helped us to find the specifications required for the construction of an automatic sorting machine which should reveal cracks in cast iron articles having rotational symmetry.
The experiments were carried out on automobile brake drums in which, for obvious reasons, cracks cannot be accepted.
Their acoustic properties resemble those of a bell: It is possible to exite standing waves, the nodes and antinodes of which form characteristic patterns. The frequency response of the test specimens contained two dominant resonant frequencies:

f_1 – 700 Hz, 4 nodal meridians 90° apart
f_2 – 1300 Hz, 6 nodal meridians 60° apart

In the experimental set-up either of the two resonant frequencies can be continuously exited. See Fig. 1.
The vibration of the test specimen (1) is measured by an Electromagnetic Transducer (2) (B & K Type MM 0002). The alternating voltage from the Transducer is passed via an Amplitude Limiter (3) to a Frequency Analyzer Type 2107 (4), which is tuned to the wanted resonant frequency. The output from the analyzer is amplified in the power amplifier of a Type 1402 Random Noise Generator (6) (the oscillator part bypassed) and led to a Type 4216 loudspeaker (7) (artificial mouth). The opening of the sound-proof housing is

*) Reinhard Kühl KG, B & K's representative in Germany.

terminated by a telescopic tube (8) of approximately 12 mm diameter, which can be tuned by varying its length. The end of the tube is directed at one of the antinodes of the test specimen (1) as is the transducer.

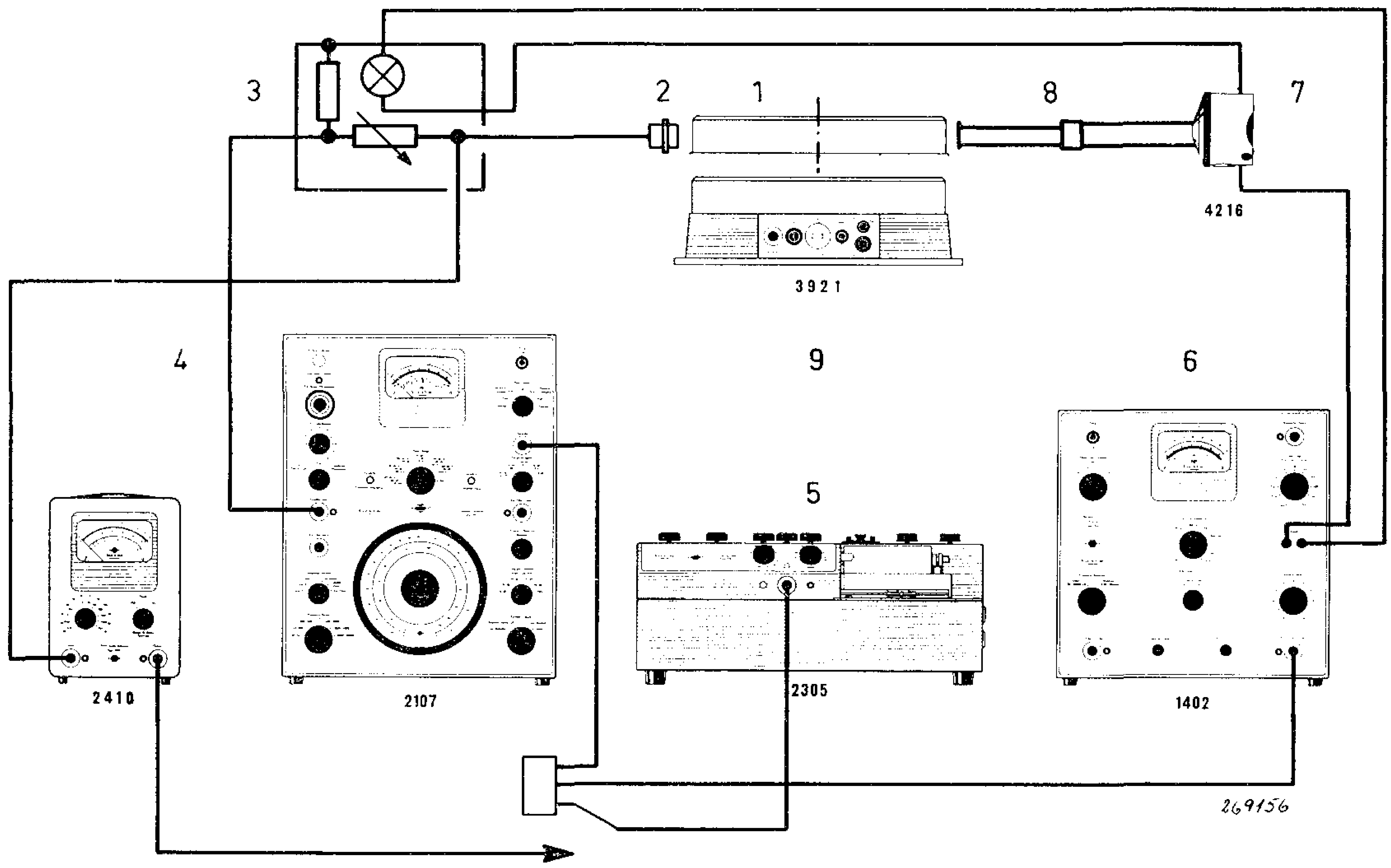


Fig. 1. Experimental set-up.

The loudspeaker current is led through an incandescent lamp (12 V/80 mA) which is placed together with a photo-sensitive resistance (ORP70), in an opaque box as part of the Amplitude Limiter. Thus the whole measuring set-up is a self-regulating feed-back system. Automatic phase regulation is not necessary as the phase is sufficiently well tuned by regulating the tube length and by detuning the Frequency Analyzer Type 2107 (at 20 dB/octave selectivity), and by assuring that the loudspeaker has correct polarity.

The settings found by experiment could be used for all specimens of the same type.

Even with the small loss factor measured ($d = 0{,}0015$), the time for the transient stage never exceeded the time used for placing the specimens on the Turntable (9) (Type 3921).

The effect of a crack, as the experiments have shown, depends on its position relative to the vibration pattern. If the crack is at a node, then the vibration is not, or is only slightly damped.

On the other hand, if the crack is at an antinode, then the vibration is heavily damped or even completely suppressed. We utilized this observation to reveal cracks: The test specimens were rotated on a Turntable so that the cracks

had to move through the nodes and antinodes. The variation of vibration level obtained hereby was recorded on a Level Recorder Type 2305 (5).
In this way a representative number of good and bad specimens of two designs were examined with the following result.
On the defective specimens, the output from the Frequency Analyzer always changed more than 10 dB when the flaw or the defect was more than 1/3 r_{max} away from the centre. It was not possible to reveal defects very near the centre.
The cracks were mainly found in the cylindrical part of the specimens (the brake surface) and in the axial direction, this is probably due to thermal stresses left after casting. Therefore we only found a few specimens where the oscillations did not start at all. In most of the specimens the oscillations started and stopped periodically. Occasionally this effect was accompanied by a jump to the other resonant frequency.
In the flawless specimens the vibration level varied up to $\pm$ 3 dB during one revolution of the Turntable. But unlike the defective specimens, the curves from these were continuous. The variations were partly due to insufficient centering of the measuring set-up. Therefore a second Type MM 0002 Transducer was added in series with the original Transducer and placed symmetrically (180°) across the test specimen.
Still a variation of $\pm$ 1 dB was present. The reason for this is probably small asymmetries in the placing of the center hole and in the unmachined parts of the casting. The second Transducer did not add further information about the cracks. One of the two brake drum designs had four ribs in the hub area. These ribs reacted with the vibration pattern of the first resonant frequency during the rotation, so this design could only be tested by utilizing the second resonant frequency. The other design could be tested using either of the two frequencies, both giving equal results.
Still the obtainable sorting frequency had to be determined.
From the theoretical reasoning we expected that the angular velocity of the turntable could be raised to $\omega_1 = \frac{\omega_o d}{n}$.

Where ω_o is the resonant frequency, n is the number of node meridians and d the loss factor of the flawless specimen.

During the test a disturbance must have time to travel from one node meridian to another. Therefore the necessary time is

$$t = \frac{1}{f \times d}$$

The loss factor was found by measuring the decay time T:

$$d = \frac{2.2}{T \times f}$$

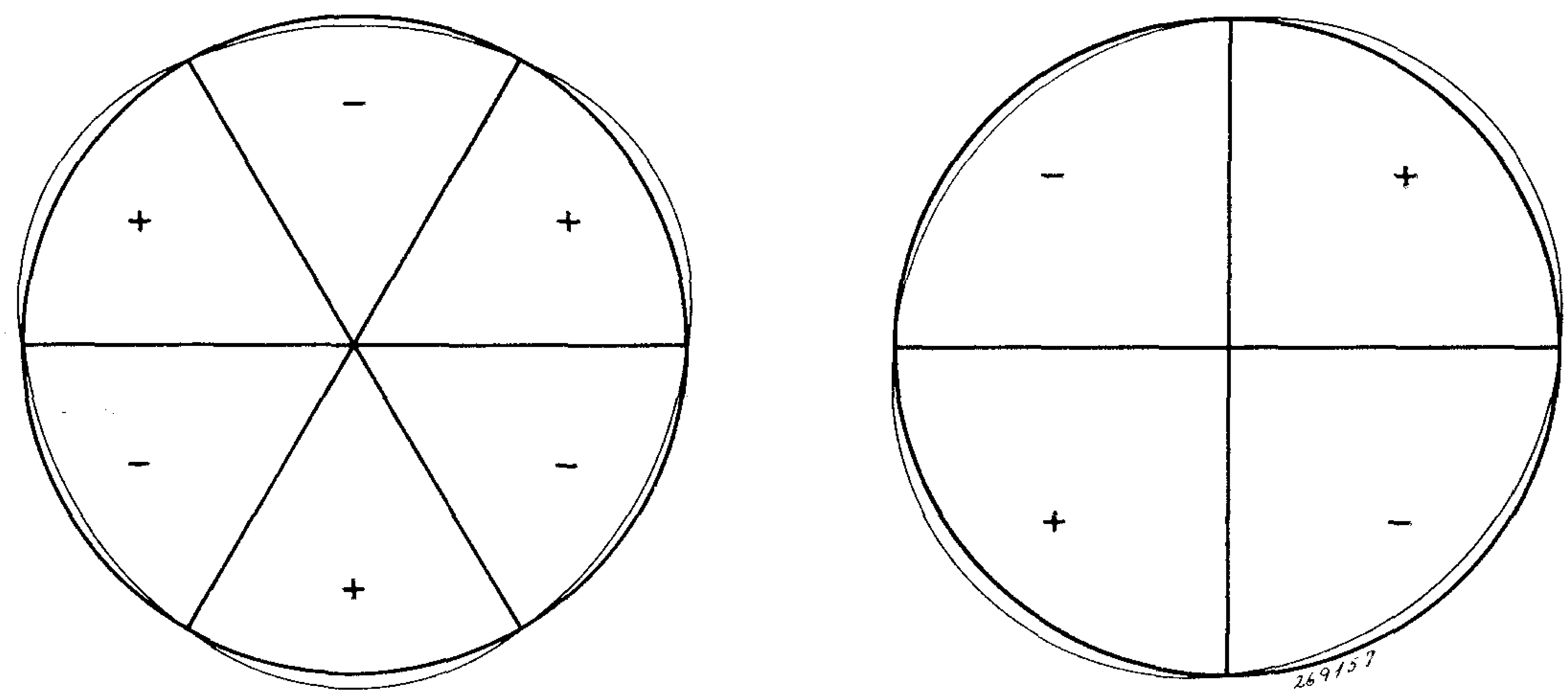


Fig. 2. Distribution of nodes and antinodes at the two resonant frequencies.

The calculation of t gave

$$t_1 = 0.94 \text{ sec for } f_1 = 700 \text{ Hz}$$
$$t_2 = 0.51 \text{ sec for } f_2 = 1300 \text{ Hz}$$

Thanks to the good regulation of the Amplitude Limiter, we found our expectations confirmed. Taking into account, the time necessary for changing the test specimens, a sorting speed of approximately 1000/hour can be expected.
Some of the elements of the experimental set-up e.g. the Transducer and the Amplitude Limiter could be used directly in an automatic sorter, however, the other elements would probably be better if specially made up to the specifications revealed by the experiment.

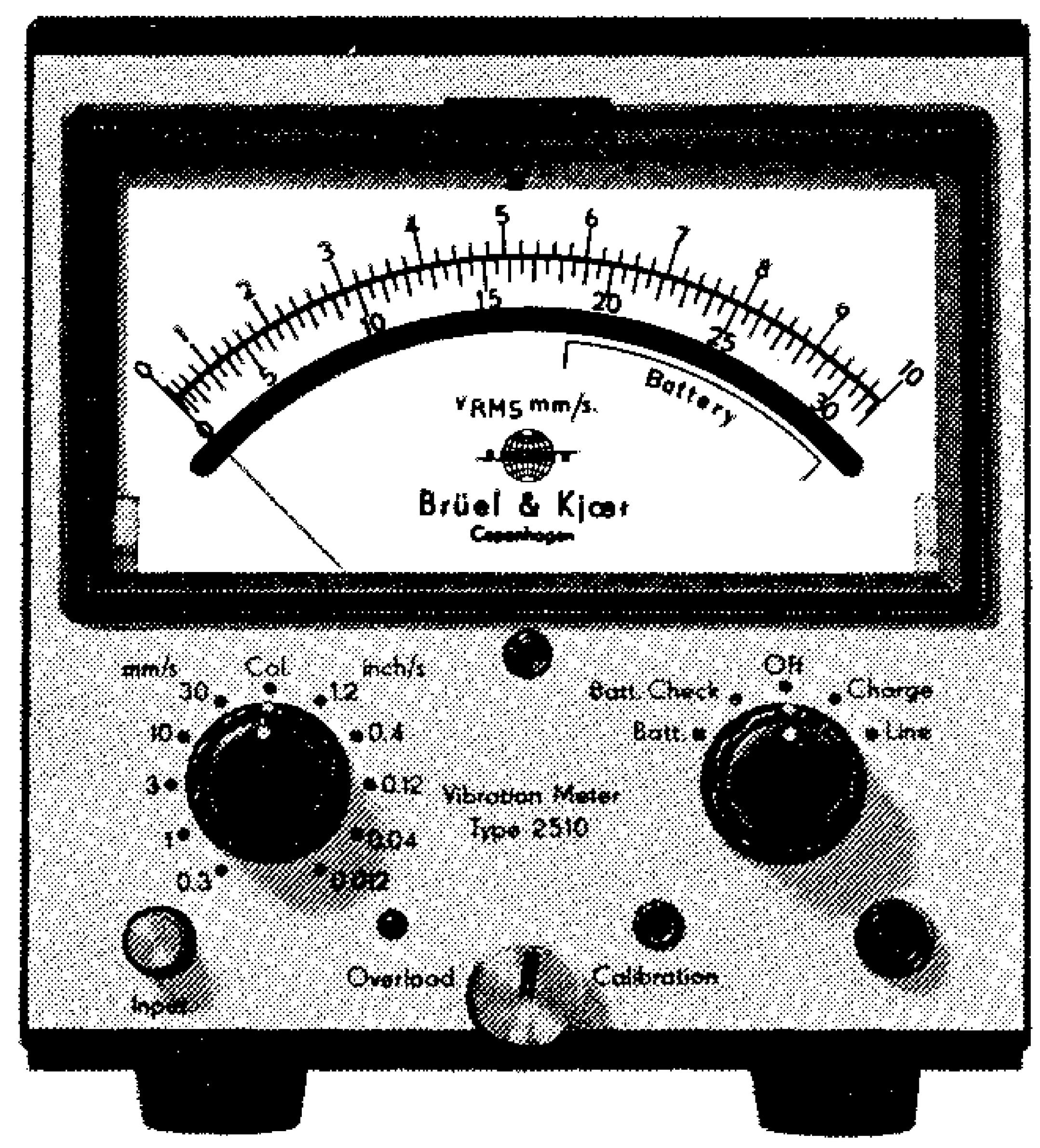
News from the Factory

Frequency Analyzer Type 2113

The frequency analyzer is the combination of the Measuring Amplifier Type 2606 and the Filter Set Type 1615. The analyzer is contained in a compact case and thus offers in a limited space, specifications far exceeding those of previous 1/3 octave analyzers.

Vibration Meter Type 2510

The Vibration Meter Type 2510 is designed for industrial use to measure and control vibrations in mechanical machinery. It is a low cost compact instrument presenting the RMS value of the vibration velocity. The measuring range is from 0.3 mm/sec to 30 mm/sec or 0.012 inches/sec to 1.2 inches/sec for full deflection.



The frequency response is flat between 10 and 1000 Hz and falls off at both ends at a rate of 18 dB/octave in accordance with the German DIN 45666 and with the proposal for ISO Recommendation ISO/TC 108/WG2 N10.

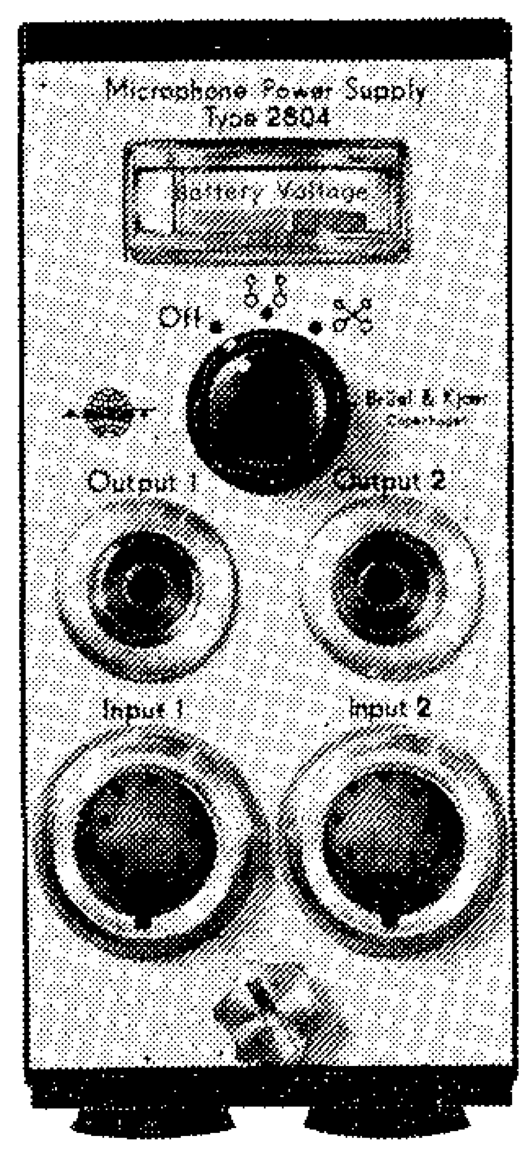
A piezoelectric accelerometer is used as the vibration transducer, and in order to achieve a constant sensitivity for different cable lengths a charge amplifier is used as input stage to the Vibration Meter. Typical value of noise is less than 5 μm/sec.

There is provision for use with external filters, and most types of recording and indicating instruments can be connected at the output.

Power can be supplied from AC mains or from internal storage batteries.

Microphone Power Supply Type 2804

This battery driven Power Supply is designed to power the Type 2619 Preamplifier.



It has two measuring channels. The outputs of these can be interchanged by a single switch thus facilitating a simple change between two measuring points. The power supply provides 28 V for the Preamplifiers and 28 V or 220 V for Condenser Microphone polarization. In addition there are two 28 V, 2 mA outputs which can be used separately or in parallell.

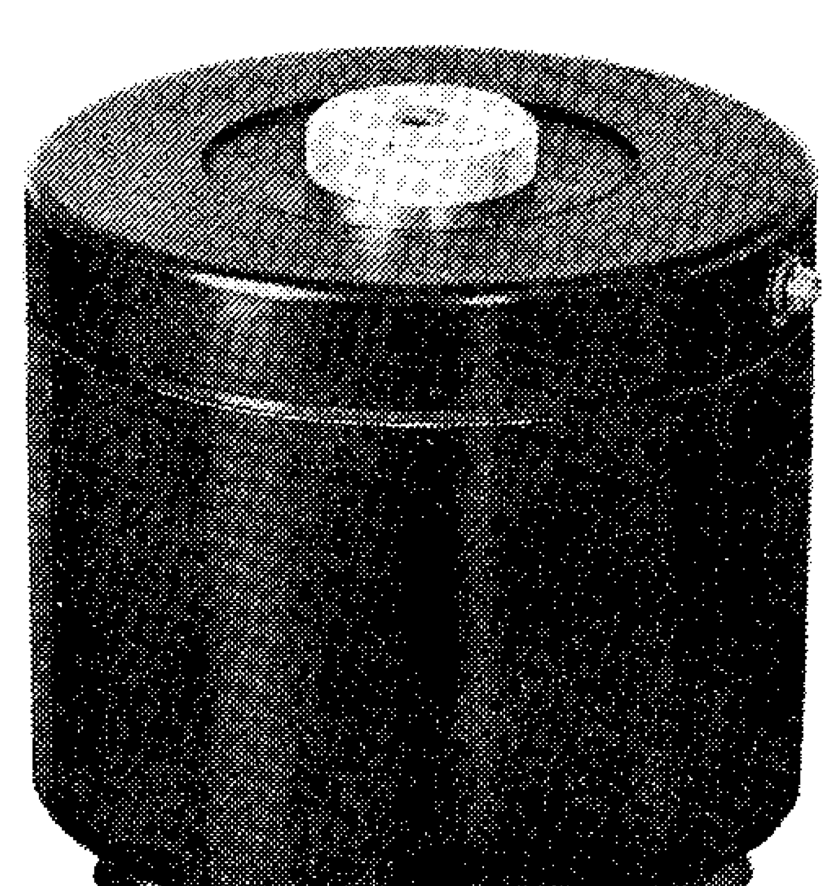
A plug is provided for external 6 V DC for the preamplifier heaters as these would drain the internal batteries too much.

Mini Shaker 4810

The Mini Shaker provides a simple solution to vibration excitation where small forces are needed over a frequency range of 20 Hz to 20 kHz.

The available force is 7 Newton at an input power of 15 VA. This force vibrates the moving mass (0.018 kg) of the shaker at 50 g peak from 65 Hz to 4 kHz and at 35 g peak at higher frequencies.

Small specimens can thus be vibrated at relatively high levels. Heavier systems can often be excited near resonance.



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(Continued on cover page 2)

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