1024

INSTRUCTIONS AND APPLICATIONS

Sine Random Generator Type 1024

This Generator has been especially designed to meet the numerous requirements of a signal source for acoustical, electrical and electro-acoustical measurements.

It can be switched to produce either a sine-wave, a narrow band of random noise or a wide band random noise output. The frequency of the sinusoidal output and the center frequency of the narrow band random output signal is tuneable manually, or automatically from an external motor. The frequency scale is logarithmic and covers the range from 20 to 20ooo Hz. An automatic output regulator makes automatic control of the output voltage possible.

BRÜEL & KJÆR

Nærum, Denmark . ☎ 80 05 00 . BRUKJA, Copenhagen . Telex: 5316

BB 1024

Sine Random Generator

Type 1024

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Contents

1. Description

General.

The Sine-Random Generator Type 1024 has been designed as a versatile multipurpose signal source for electrical and acoustical measurements. It covers the frequency range from 20 to 20ooo Hz*) and consists of a wide band noise generator, a beat frequency oscillator, several filters and amplifiers and an automatic output regulator (compressor). At the output terminals the following three types of output signals can be obtained:

1. Sine Wave
2. Narrow Bands of Random Noise
3. Wide Band Random Noise

The basic principle of operation of the Sine-Random Generator is shown in the form of a block diagram in Fig. 1.1. In position Sine-Wave and Narrow Bands of Random Noise the generator works on the heterodyne principle using two mixers, and in position Wide Band Random Noise the signal from the noise generator is fed via a low-pass filter directly to the output amplifier.

The frequency of the sine-wave signal and the centre frequency of the narrow band of random noise, can be read off a large illuminated scale the pointer of which is connected to the variable capacitor. The scale is logarithmic and graduated from 20 to 20ooo Hz. An INCREMENTAL SCALE is also provided, allowing exact frequency selection in the range — 50 to + 50 Hz around any setting on the main scale.

The frequency alignment is checked by obtaining a beat between the frequency of the mains voltage and that of the Generator, the latter being tuned to the frequency of the mains and the METER SWITCH set to position "Power Frequency Beat".

A worm gear arrangement permits the tuning capacitor to be driven automatically from an external drive, for example with the aid of the motor in the Level Recorder Type 2305.

Also, a compressor circuit has been included in the instrument. The compressor circuit can be controlled from an external voltage, whereby it is possible to keep the voltage, current, vibration or sound pressure level constant during measurements where the Generator is used as sine-wave or narrow band noise signal source.

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*) Hz: International = c/s: Used in the United Kingdom and U.S.A. (in U.S.A. also: Hz = cps).

Operation as Beat Frequency Oscillator.
The main operating principle of the Generator is actually the same whether it is switched to supply a sine wave or a narrow band noise signal to its output terminals, namely the so-called beat frequency, or heterodyne, principle. This consists in suitable frequency transformations of the original signal, allowing operations such as automatic output regulation and band shaping of the noise to be most conveniently achieved. Referring to the block diagram Fig. 1.1 these transformations are as follows:

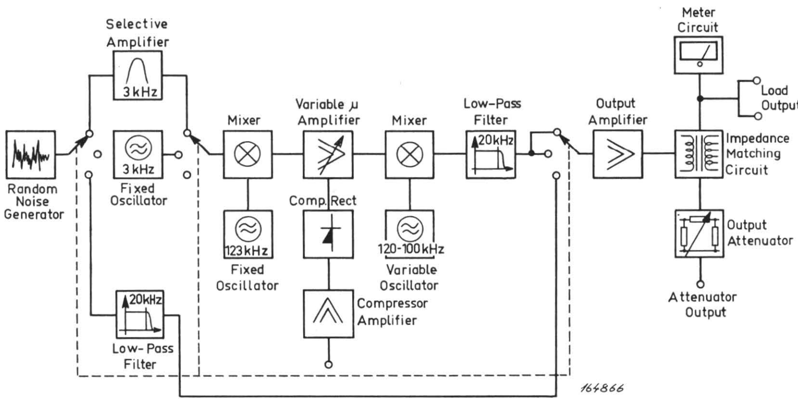

Fig. 1.1. Block diagram of the Sine-Random Generator.

a. **Sinusoidal.**
A 3 kHz oscillator modulates a 123 kHz carrier signal. The lower sideband (120 kHz) of the modulated signal is separated in an i.f. amplifier which, incidentally, acts simultaneously as a regulation amplifier. After the lower side-band has been selected, the signal is mixed with a signal of frequency between 100 kHz and 120 kHz originating in a variable oscillator. A low-pass filter (cut-off, 20 kHz) selects the difference frequency which is amplified in the Output Amplifier before being passed on to the output and meter circuits.

b. **Narrow-Band Noise.**
The sequence is the same as that just described except that instead of modulating the 123 kHz with 3 kHz sine wave, a 3 kHz signal of randomly varying amplitude is used. This is derived by filtering and amplifying a wideband noise signal.

The 3 kHz Oscillator and Selective Amplifier.
The 3 kHz selective amplifier and 3 kHz oscillator are shown as separate units in the block diagram (Fig. 1.1), but in fact they are one unit, switched to the correct function as required.

When the Generator is switched to sine wave operation the tuned circuits in the amplifier is used in a feedback arrangement, causing the amplifier to operate as a 3 kHz oscillator.
In the narrow band random conditions the feedback circuit is changed into an ordinary filter circuit passing a band of random noise from the wide band noise generator. The bandwidth of the circuit can be varied in four steps, see Fig. 1.2.

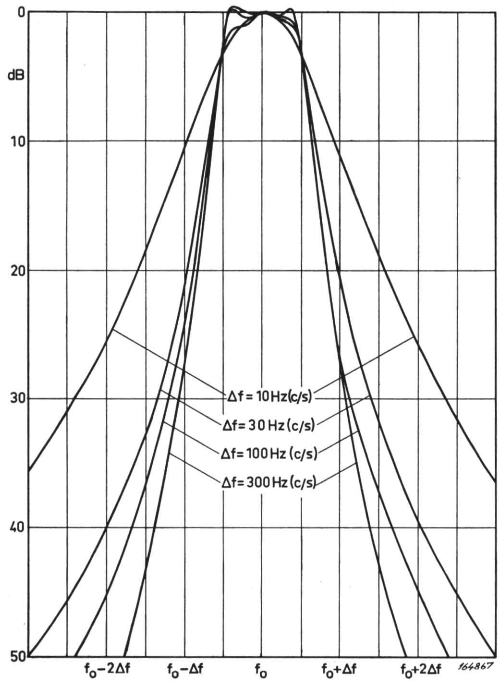

Fig. 1.2. Typical Spectrum characteristics of the various narrow noise bands.

The 123 kHz Oscillator and Modulator (Mixer).
The output from the 3 kHz oscillator and selective amplifier is fed to a balanced modulator where it is mixed with the signal from a 123 kHz fixed oscillator.

Actually the signal from the 123 kHz oscillator arrives at the modulator via a buffer stage. This buffer stage also allows the 123 kHz signal to be taken from the cathode of the tube and applied to a set of terminals at the rear of the instrument for special purposes, offering a relatively low output impedance.
From the 123 kHz modulator the lower sideband (120 kHz) is selected by a double tuned filter and fed to the variable-μ amplifier.

The Variable-μ Amplifier.

The variable-μ amplifier contains two pentodes in cascade the grid bias' of which are controlled from the output of a regulating (compressor) amplifier. By using two cascaded stages a very steep regulation characteristic and a wide dynamic range has been obtained, Fig. 1.3. The regulation is obtained by biasing the pentodes near cut-off on the Ia-Eg characteristic, whereby even small changes in bias change the amplification of the stages considerably.

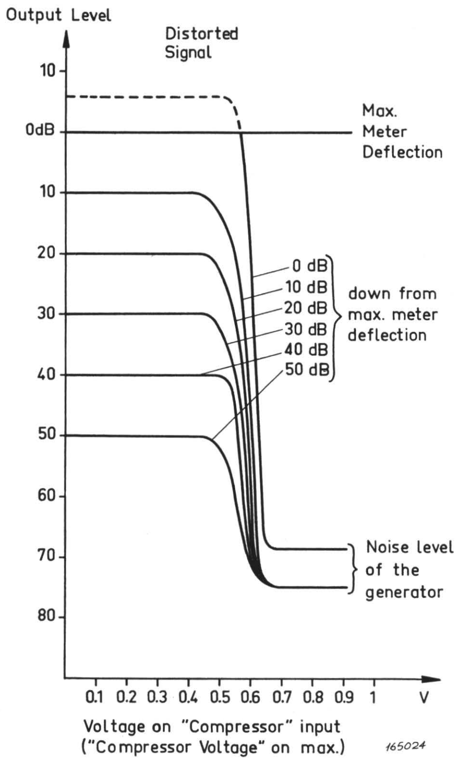

Fig. 1.3. Regulation characteristics for different positions of the potentiometer marked OUTPUT LEVEL.

To make regulation of the output level possible even when maximum output power is required from the Generator, the signal level from the balanced modulator is raised approx. 10 dB when the automatic regulation is switched in. By means of a noiseless switch on the front panel, marked OSCILLATOR STOP, the working-point of the pentodes in the variable-μ amplifier can

be switched to the cut-off point, and in this way the output signal will be disconnected.
The anode circuits of the pentodes are tuned to 120 kHz, thus forming a very selective bandpass filter. As the regulation principle employed makes use of nonlinear characteristics nonlinear distortion is introduced but is again removed by means of this filter. A "clean" 120 kHz tone (or narrow band of noise) is therefore fed to the second modulator (mixer).

The Variable Oscillator, Mixer (Second) and Low-Pass Filter.

The frequency of the variable oscillator (see Fig. 1.1) can be altered continuously from 120 to 100 kHz by means of a specially designed variable capacitor. This capacitor is made with a high degree of accuracy and a maximum deviation of o.7 degrees from a logarithmic frequency curve is obtained. A worm gear connected to the capacitor spindle, permits automatic frequency scanning with the aid of an external motor, e.g. the motor in the Level Recorder Type 2305, and the worm gear can be set and released by means of a magnetic clutch. This is operated from a switch on the front panel of the instrument or it can be operated from an external switch or relay. Connection must then be made to the appropriate terminals of the socket marked REMOTE CONTROL on the front panel, and the scanning control switch which controls the operation of the magnetic clutch must be in position "Scanning Off".
The rear end of the scale pointer spindle is provided with a 6 mm hole for the attachment of special purpose devices which are to be governed by the angular position of the frequency scale pointer.
The voltage developed across the grid of the variable oscillator is fed to the mixer (second) via a buffer stage. In the mixer it is mixed with the voltage from the variable-μ amplifier and the lower sideband of the modulated signal is now selected by a low-pass filter having a limiting frequency of 20 kHz. A signal is thus obtained the frequency of which can be varied continuously in the range 20 Hz—20 kHz by means of the above described variable oscillator.
The frequency can be read off an individually calibrated, true logarithmic scale. From the low-pass filter the signal is fed to the output amplifier via a potentiometer marked OUTPUT LEVEL.

The Output Amplifier.

The OUTPUT LEVEL potentiometer is situated in the grid circuit of the first stage in the output amplifier and allows continuous regulation of the Generator output voltage. The gain of this amplifier is stabilized by means of negative voltage feedback and the anode circuit of the output tube is coupled to an auto-transformer for impedance matching. See Fig. 1.4. Four different output impedances are available and can be chosen with the switch on the front panel marked MATCHING IMPEDANCE.

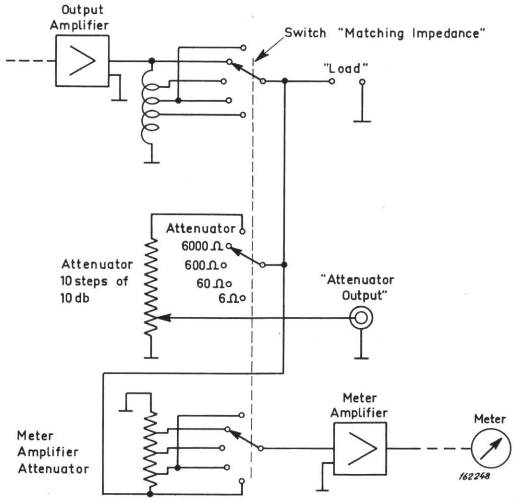

Fig. 1.4. Schematic diagram of the Generator's output circuitry.

The different positions of the switch are indicated by 6, 60, 600 and 6000 ohms respectively, and the output voltage is taken from the terminals marked LOAD. It should be noted that the output impedance of the generator is only approximately 10—20 % of the indicated values but when loading with impedances as marked a maximum output power is obtained with a minimum harmonic content. Furthermore, correct loading ensures the output voltage to be practically independent of the frequency.

A fifth position of the switch MATCHING IMPEDANCE is marked "Att." and connects the output transformer to an attenuator, which is variable in steps of 10 dB and operated by the switch marked ATTENUATOR on the front panel.

In narrow band (or wide band) random noise operation the total range of the attenuator is from 4 V to 0.04 mV. In sine wave operation the range is from 12 V to 0.12 mV.

When the MATCHING IMPEDANCE switch is in position "Att." the output circuit is connected to the screened socket on top of the front panel, the output impedance being constant and approximately 50 ohms. The overall accuracy of the attenuator is approximately 2 %.

The r.m.s. level of the output signal, noise or sine-wave, can be read on a built-in indicating meter, and the sensitivity of the voltmeter is automatically changed when the position of the switch marked MATCHING IMPEDANCE is altered. Full deflection of the meter is indicated on the switch. When the MATCHING IMPEDANCE switch is in position "Att." the output voltage available from the generator will depend on the position of the ATTENU-

ATOR switch and in this case the deflection of the meter corresponds to the value indicated by this switch position. In addition to the volt calibration on the switch ATTENUATOR OUTPUT there is also a dB calibration which is given in dB re. 1 volt. An example will explain the use of the dB scale: If the OUTPUT LEVEL is adjusted in such a way, that 20 dB is read on the meter scale, and the switch ATTENUATOR OUTPUT is in the position —30 dB then the signal level at the output socket will be 20—30 = —10 dB re. 1 volt (o.316 V).

The Rectifier and Meter Circuits.

The indicating meter section contains an amplifier, a full wave (quasi) r.m.s. rectifier, a Miller integrator, and an indicating meter. Various time constants can be selected for the signal rectifier thus ensuring sufficient averaging time even for the very narrow noise band of $\Delta f = 10$ Hz.

The meter can be switched to measure either the output voltage as described under "The Output Amplifier" above, or the voltage applied to the regulating (compressor) amplifier at the COMPRESSOR INPUT socket. This latter condition has been included mainly because the narrow band noise signals can only be measured properly by an instrument with a sufficiently long averaging time. If, f.inst. an ordinary electronic voltmeter is used to check the

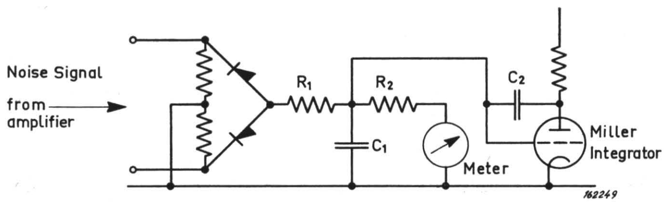

Fig. 1.5. Schematic diagram of rectifier circuit and associated Miller integrator.

compressor input voltage when this consists of a narrow band noise signal the meter pointer will show so great fluctuations that it may be practically impossible to determine the actual r.m.s. value of the signal. Also the Generator may be used directly as an r.m.s. voltmeter, although it is only operable on a single voltage range.

The long time constants desirable for the measurement of narrow band noise signals are obtained by using a socalled Miller integrator circuit. This circuit has the effect of electronically amplifying the influence of a capacitor.

The Miller integrator used here is provided with a cathode follower to obtain a sufficiently low output impedance. The value of C_1 in the rectifier circuit (Fig. 1.5) is altered by changing the value of C_2, by means of the switch marked METER SWITCH TIME CONSTANT. The arrangement of *different* meter time constants is of great advantage as an unnecessarily high value

of the capacitor C_1 results in an inconveniently high time constant (damping) of the indicating meter circuit and thus unnecessarily long measurement time. By the meter time constant is here meant the time it takes, from disconnecting the signal until the meter pointer has fallen to 1/3 of the deflection. Five values of the time constant o.3 — 1 — 3 — 10 and 30 sec. can be selected.
The indicating meter itself is a moving coil instrument, fully protected against overload, and has a sensitivity of approximately 40 μA for full scale deflection. To obtain a reading without parallax error, the scale is mirrored. The meter is provided with two linear voltage scales, and one dB scale, all illuminated by a built-in pilot lamp.

The Regulating (Compressor) Amplifier.
By means of the regulating amplifier an audio frequency control signal applied to the COMPRESSOR INPUT socket will be amplified, rectified and filtered and used to bias the tubes in the variable-μ amplifier.
A variable potentiometer marked COMPRESSOR VOLTAGE is inserted in the input circuit of the regulating amplifier and can be used as volume control for the output power when automatic regulation is employed.
Care must be taken, however, not to use a modulated DC voltage as regulation voltage as the input circuit is directly coupled. The regulating amplifier has a linear frequency characteristic from 20 to 20ooo Hz and should have an input signal of approximately o.5 Volt for full regulation. To check that the input voltage is high enough for full regulation it can be measured by setting the METER SWITCH to one of its "Compressor Input" positions.
The input impedance, measured across this socket is approximately 25 kΩ and the maximum obtainable range of regulation is 50 dB (Fig. 1.3). The amplified A.F. control voltage is rectified in a full-wave rectifier designed to give a DC output voltage proportional to the average value of the A.F.-control voltage.
By means of the switch marked COMPRESSOR SPEED on the front panel of the instrument the regulation speed can be varied. Regulation speeds of 3 — 10 — 30 — 100 — 300 and 1ooo dB/sec may be chosen by changing the value of the resistor in the A-C filtering network for the rectified control voltage. When the switch COMPRESSOR SPEED is in position "Comp. off" the output from the rectifier is short-circuited thereby disconnecting the automatic regulation circuit.

Operation as Wide Band Random Noise Generator.
By switching the instrument to the Wide Band Random Noise condition, the signal from the noise generator is fed via a low-pass filter, the cut-off frequency of which is 20 kHz, to the output amplifier see Fig. 1.1.
The wide band noise generator supplies a signal with constant power spectral density in the frequency range 20—20ooo Hz with a truly Gaussian instantaneous voltage distribution up to 4 σ (four times the r.m.s. value).

The noise generating circuit is a special B & K design, using two zener diodes as the primary noise source (see Fig. 1.6). A stabilized DC current ensures that the diodes work at the point on their characteristic which gives the highest noise voltage. By adding these two signals a noise signal with the said symmetrical Gaussian amplitude distribution is obtained.

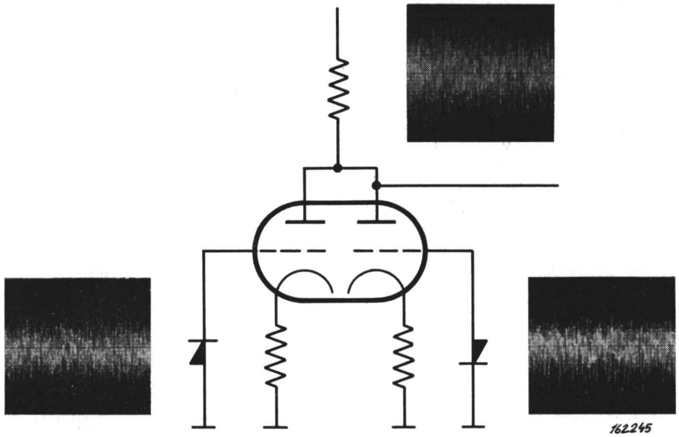

Fig. 1.6. Schematic illustration of the noise source arrangement.

Power Supply.
The power supply section is made up of the anode supply and three separate heater and relay supplies. The various voltages are taken from four separate windings on the mains transformer and the primary of this transformer is provided with taps which allows the apparatus to be used on mains voltages of 100, 115, 127, 150, 220, or 240 V. The correct value is easily selected with a special selector on the rear of the apparatus. This selector is combined with the fuseholder which contains the fuse (medium lag) connected in circuit with the primary winding of the transformer. A two-pole switch marked POWER is inserted in the primary circuit of the mains transformer.
The DC voltage for the anode supply is taken from a full-wave semiconductor rectifier via a smoothing filter. To obtain stable working of the Sine-Random Generator even with mains voltage fluctuations of $\pm$ 10 % the anode voltage is stabilized for the critical tubes in the circuit.
To achieve a very low hum level at the output of the Generator, the heaters of the tubes with low signal levels are DC supplied. This DC voltage is derived from a separate winding on the mains transformer, rectified in a full-wave semiconductor rectifier and smoothed. The voltage for the built-in relays is also supplied from this DC source.
The heater voltage for the remaining tubes and for the meter scale lamp is AC supplied from two other transformer windings.

Signal-to-Hum and Signal-to-Noise Ratios.

By the Signal-to-Hum ratio of the Sine-Random Generator is here meant the ratio between the maximum r.m.s. value of the output signal and the r.m.s. value of the hum induced in the Generator from the line voltage. This ratio is greater than 60 dB when the Generator is switched to wide band random noise operation and greater than 70 dB in the narrow band noise and sine wave cases.

With regard to the signal-to-noise ratio this is greater than 65 dB for narrow band noise and sine wave operation. The extraneous noise (except the hum components) will not disturb the output signal when the Generator is switched to its wide band random noise condition and the signal-to-noise ratio may thus in this case be considered "infinite".

Distortion.

To give an un-ambiguous representation of the distortion factor, it is measured for sine-wave signals. From these measurements the distortion of the noise signal can then be judged in the individual cases. Typical values are represented by curves in Fig. 1.7. Three curves are given: one for the

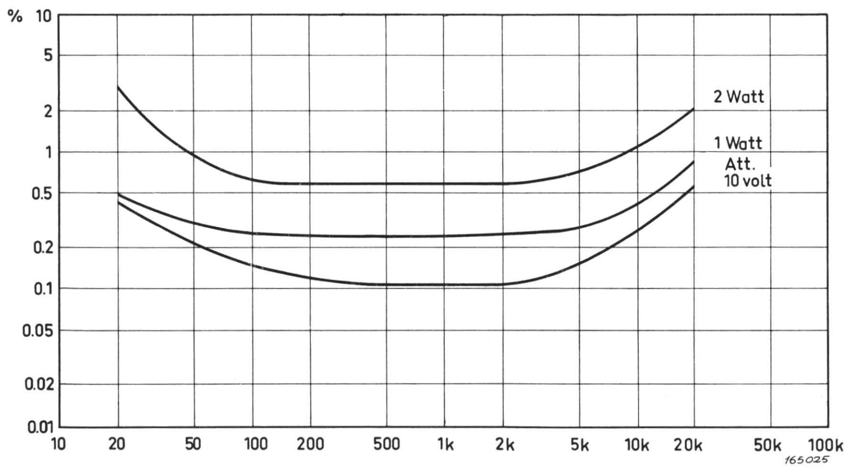

Fig. 1.7. Distortion curves for different loads.

unloaded output, measured at the ATTENUATOR output, and two for loaded conditions measured at the terminals LOAD. The curve, valid for the unloaded Generator, is measured at 10 V r.m.s. sine-wave, i.e. amplitudes, below 14 V in a noise signal will be distorted respectively less or equal to the values given by the curve. The two curves valid for the loaded Generator are measured at 1 Watt and 2 Watts respectively sine-wave average power.

This corresponds to instantaneous noise peak power magnitudes of 2 and 4 Watts respectively.

$$\text{Power} = \frac{V^2 \text{ (r.m.s.)}}{R} \qquad \text{Peak Power} = \frac{(V \text{ r.m.s. } \sqrt{2})^2}{R}$$

From the "power" curves in Fig. 1.7 can be found the average noise power available for a noise signal with a particular crest factor f_c, the peaks of which have to be kept below a certain distortion limit. In other words, if the distortion of noise peak magnitudes of interest has to be below e.g. 0.5 %, the instantaneous noise peak power should never be higher than 2 Watts (1 Watt curve) for the middle frequencies, see Fig. 1.7. If now the signal considered should allow for a crest factor $f_c = 4$, the maximum average noise power drawn from the Generator has to be less than:

$$\frac{W \text{ peak}}{(f_c)^2} = \frac{2}{4^2} = \mathbf{0.125 \text{ Watt}}$$

That the Noise Generator supply is below this, so derived noise power (0.125 W), can be calculated from the indicating meter deflection and the load resistance.

Note: The maximum available practically undistorted peak voltage is 160 V (open circuit).

2. Control Knobs and Terminals

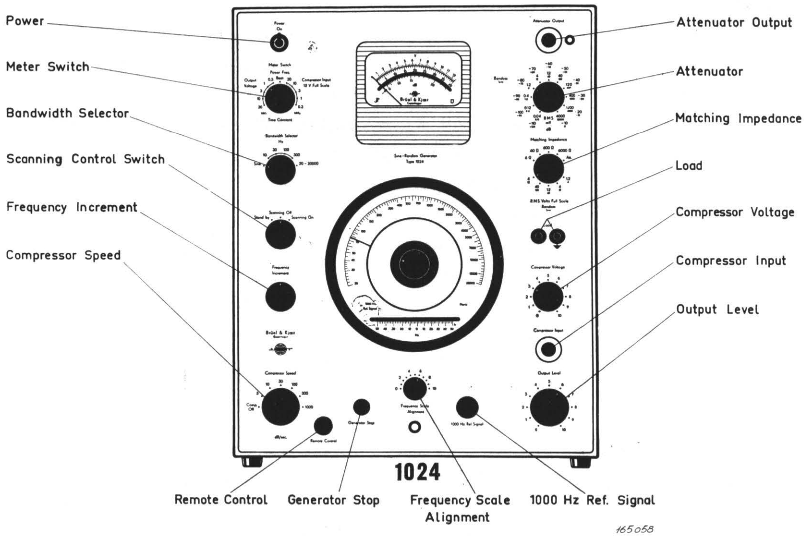

Fig. 2.1. Sine Random Generator Type 1024 front panel.

POWER: To switch the power on and off for complete apparatus. When switched on the indicating meter and frequency scales are illuminated.

METER SWITCH: **"Output Voltage".** The r.m.s. level of the signal available on the terminals LOAD or ATTENUATOR OUTPUT can be measured. The markings around the knob refer to the various, selectable meter time constants.

"Power Frequency Beat". In this position the complete Generator can be frequency calibrated against the mains supply frequency.

"Compressor Input". The r.m.s. level of the signal applied to the COMPRESSOR INPUT socket can be measured. Full meter scale deflection for 12 V r.m.s. The markings around the knob refer to the various selectable meter time constants.

The time constant values "o.3", "1", "3", "10" and "30" sec. indicate the time it takes the meter pointer to fall, when disconnecting the signal, to 1/3 of the original deflection.

BANDWIDTH SELECTOR:

"Sine". In this position the Generator supplies a sine-wave signal to the output terminals LOAD or ATTENUATOR OUTPUT.

"10", "30", "100" and "300" indicate the 3 dB bandwidth in Hz of the noise bands available at the terminals LOAD or ATTENUATOR OUTPUT. The shapes of the noise bands are illustrated in Fig. 1.2.

"20—20ooo". A noise signal with uniform spectrum density (white noise) in the frequency range 20—20ooo Hz and with Gaussian instantaneous amplitude distribution is present at the terminals LOAD or ATTENUATOR OUTPUT. In this case the compressor arrangement will not operate.

SCANNING CONTROL SWITCH:

"Stand by". The output signal of the Generator is suppressed by the compressor circuit by more than 70 dB relative to full drive.

"Scanning Off". The automatic frequency scanning drive is stopped instantly.

"Scanning On". The automatic frequency scanning drive is started instantaneously.

FREQUENCY INCREMENT:

To allow small variations (± 50 Hz) to be made in frequency around the setting of the main frequency scale.

COMPRESSOR SPEED:

The switch allows the compressor (regulation) speed in the servo loop to be adjusted. When in position "Comp. Off" the servo is inoperative. "3", "10", "30", "100", "300" and "1ooo" indicate the servo regulation speed in dB/s.

REMOTE CONTROL: For external connections when remote control of the electromagnetic clutch and/or oscillator stop is desired. Plug JP 4705 will fit the remote control socket.

When the Generator is delivered from the factory it is supplied with a plug JP 4725 which is a JP 4705 with certain internal connections. These connections are necessary to suppress the output signal in the uncalibrated section of the frequency scale from 20 kHz—20 Hz.

GENERATOR STOP: When pressed the output signal from the Generator disappears instantly.

FREQUENCY SCALE ALIGNMENT: For frequency calibration of the Generator. Changes the frequency of the variable oscillator. The screw-driver operated control is for coarse adjustment in case the range of the fine adjustment control is not sufficient.

1000 Hz REF. SIGNAL: Pushbutton. When pressed the output signal frequency will change to 1000 Hz assuming the Frequency Main Scale is set to the mark "1000 Hz Ref. Signal" and the Frequency Increment Scale is on "0"

OUTPUT LEVEL: Continuously variable potentiometer located at the input of the output amplifier, thus affecting both the outputs LOAD and ATTENUATOR OUTPUT.

COMPRESSOR INPUT: Input socket for the compressor voltage. For full regulation a voltage of approximately 0.5 Volt is necessary. Plug JP 0018 fits this socket.

COMPRESSOR VOLTAGE: Logarithmic potentiometer for attenuation of the regulation voltage on COMPRESSOR INPUT.

LOAD: Terminal set presenting various output impedances. Refer also to item MATCHING IMPEDANCE below. The right hand terminal is grounded. Banana plugs fit the terminals.

MATCHING IMPEDANCE: "6 Ω", "60 Ω", "600 Ω" or "6000 Ω" loads can be connected in the respective positions. The actual output impedance is 10—20 % of the stated value. The voltages indicated by MATCHING IMPEDANCE

are the r.m.s. voltages obtainable in the respective positions for full meter scale deflection. Small figures to be used with sine-waves and large figures with random noise signals.
"Att.". The output voltage is available on the terminal ATTENUATOR OUTPUT.

ATTENUATOR OUTPUT: When MATCHING IMPEDANCE is set to "Att.", the output signal to the ATTENUATOR OUTPUT socket can be regulated in steps of 10 dB by means of the knob marked ATTENUATOR.

ATTENUATOR: The values indicated by the knob positions correspond to the r.m.s. mV available at full scale indicating meter deflection. Small figures to be used with sine-waves and large figures with random noise signals. The plug JP 0018 will fit the ATTENUATOR OUTPUT socket.

3. Operation

General.

Ascertain that the Sine-Random Generator is set to appropriate power supply voltage by means of the selector at the rear of the instrument. After connection to the power supply, the instrument can be switched on by the toggle switch marked POWER on the front panel. The dial lights in the meter and frequency scale should come on immediately. When the Generator is to be used in the Sine-Wave or Narrow Band Random Noise condition, a calibration of the frequency scale should be carried out.

A. Calibration of the Frequency Scale.

1. Snap the toggle switch marked POWER to "On" and allow two minutes warm up.
2. Set BANDWIDTH SELECTOR to "Sine" position.
3. Set SCANNING SWITCH CONTROL to "Scanning off".
4. COMPRESSOR SPEED to "Off" position.
5. Set suitable deflection on the meter by turning the knob marked OUTPUT LEVEL to higher than center scale reading.
6. Turn the main scale pointer until it is at the frequency of the mains voltage and check that the incremental frequency scale is on zero. If not, set by FREQUENCY INCREMENT knob to this point.
7. Set METER SWITCH to "Power Freq. Beat" position. Knobs not mentioned can remain in any position.
8. Rotate FREQUENCY SCALE ALIGNMENT (the black knob) slowly, until a large fluctuation registers, slows up, and practically ceases on the meter dial. If the scale is widely out of tune, two points may be found where this occurs, only one of which is correct and therefore a check and coarse adjustment as outlined in the following paragraph should be carried out.
9. Set the METER SWITCH to its "Output Voltage" position. Then turn the main scale pointer to twice the mains frequency. If the Generator is improperly tuned the instrument meter needle drops to zero. To realign use the following procedure: Set the main scale pointer to 20 Hz and the frequency increment scale pointer to —20 Hz. Turn the knob FREQUENCY SCALE ALIGNMENT to its center position between 4 and 6 and rotate the screwdriver operated FREQUENCY SCALE ALIGNMENT adjuster until the instrument meter pointer drops to 0. Reset the incremental frequency scale pointer to zero and the main scale pointer to the frequency of line voltage. Set the METER SWITCH to its "Power Freq. Beat" and repeat item 8 above.

B. Operation Using the Output Terminals marked LOAD.

For Sine-Wave and Narrow Band of Random Noise condition set-up and calibrate as described in A.

1. Set BANDWIDTH SELECTOR to the desired output signal.
3. Set METER SWITCH to "Output Voltage" and choose the lowest value of meter time constant where no fluctuation of the meter pointer is visible.
3. Set SCANNING CONTROL SWITCH to "Scanning off". For automatic scanning see item D.
4. Set COMPRESSOR SPEED to "Off" (for automatic regulation of output power see item E).
5. Place the MATCHING IMPEDANCE switch in a suitable position for the application.
   Note: Full deflection on the instrument meter corresponds to the voltage indicated by switch position. Large figures for the noise condition and small figures for the sine-wave signal.
6. Connect the load to the output terminals marked LOAD.
7. Turn the pointer on the main frequency dial to the desired frequency.
8. Select a suitable output voltage by turning the knob marked OUTPUT LEVEL.

C. Operation Using the Built-in Attenuator.

Apply the following procedure:

1. Set up as described in item B to B 5.
2. Set the MATCHING IMPEDANCE switch to the position "Att". Select the appropriate voltage range by means of ATTENUATOR.
   Note: Full deflection of the instrument meter corresponds to the voltage indicated by switch position. Large figures for the noise condition and small figures for the sine-wave signal.
3. Connect the load to the screened output socket at the top of the instrument marked ATTENUATOR OUTPUT.
4. Proceed as in B 7 and 8.

D. Automatic Recording.

By combining the Sine-Random Generator Type 1024 and the Level Recorder Type 2305, or using the Automatic Frequency Response Recorder Type 3309 it is possible to obtain an automatic recording. When using the Generator and the Level Recorder, it is necessary to connect the two instruments mechanically by a Flexible Shaft UB 0041. For setting-up, calibrating and synchronizing the following procedure should be adapted.
Ensure that the power supply voltage selectors are correctly set on both instruments and switch POWER toggles to the "On" position, then.

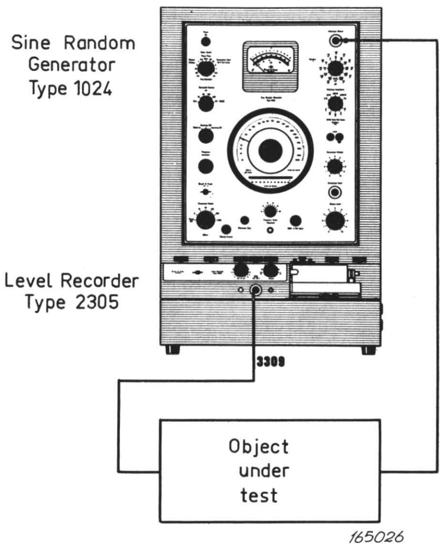

Fig. 3.1. External electrical connections when using Automatic Frequency Response Recorder Type 3309. If necessary an amplifier can be used between the test object and the Level Recorder.

The Sine-Random Generator.

1. Calibrate the generator as described in A.

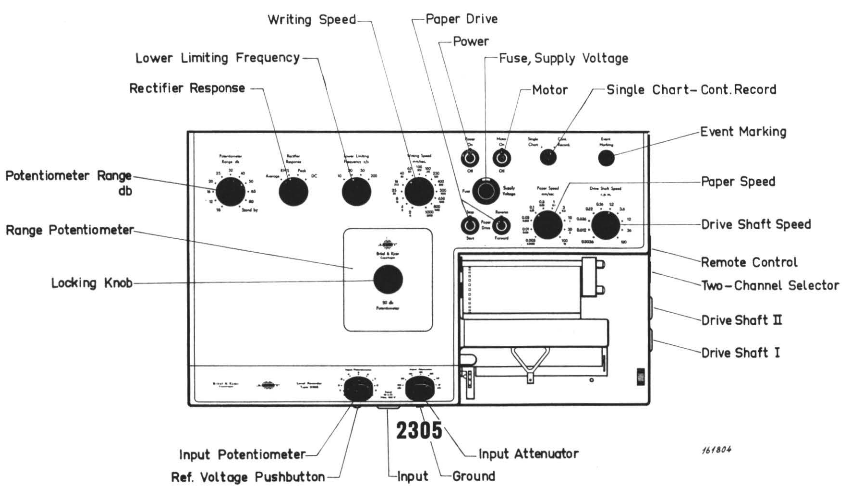

Fig. 3.2. Level Recorder Type 2305 viewed from above.

2. Connect the instruments. If using the Sine-Random Generator and the Level Recorder the Flexible Shaft UB 0041 should be connected between DRIVE SHAFT 1 on the right-hand side of the Level Recorder and the drive socket on the left-hand side of the Generator.

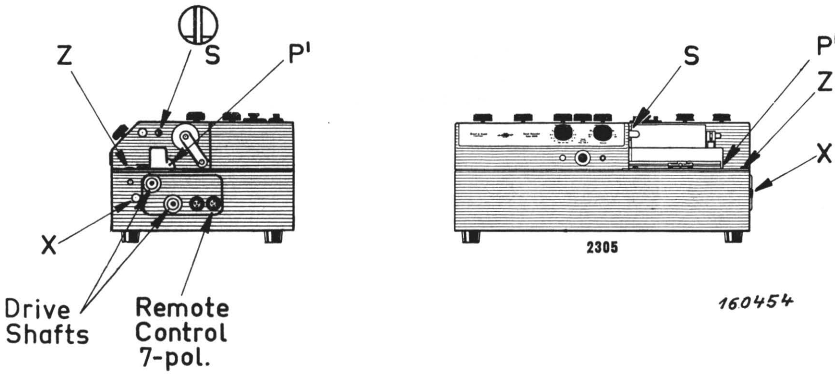

Fig. 3.3. Front and side views of the Level Recorder.

The Level Recorder (see also Figs. 3.2 and 3.3).

1. Switch PAPER DRIVE to "Stop" and continue with the following procedure refering to Fig. 3.2.
2. Load the Level Recorder with the desired recording paper. (Follow instruction in Level Recorder Manual).
3. Select and insert required Range Potentiometer (Note: POTENTIOMETER RANGE dB switch to "Stand by" when changing potentiometers).
4. Switch POTENTIOMETER RANGE dB until figure corresponds to the Range Potentiometer being used, i.e. "10", "25", "50" or "75" ("80").
5. By means of the switch RECTIFIER RESPONSE, select R.M.S. or if specially required one of the other three positions Average, Peak, or DC.
6. Turn the LOWER LIMITING FREQUENCY switch to the cut-off value 2, 10, 20, 50 or 200 Hz.
7. Set WRITING SPEED to required position (full explanations of items 5, 6 and 7 can be obtained from the Level Recorder Manual).
8. Place REVERSE-FORWARD switch to "Forward".
9. Switch PAPER SPEED to a suitable speed e.g. 10 mm/sec.
10. Pull gear-lever marked X to the outer position (see Fig. 3.3). The actual paper drive speed now corresponds to the small numbers, marked around the PAPER SPEED knob.
11. Two types of recording can be made:—
    (a) Single chart recording (automatic recording over a length of 250 mm paper only).

(b) Continuous recording over any length of paper.

(a) **Single Chart Recording.**
Set the PAPER DRIVE toggle switch to "Start" thus commencing the paper to run, which will continue until the built-in automatic stop switch declutches the drive mechanism (less than one chart length).
Reset recording paper by finger wheel Z (Fig. 3.3) until the stylus rests on the 10 Hz line.
A chart of 250 mm length will now run off when the SINGLE CHART - CONTINUOUS RECORDING pushbutton is pressed and released again after a few seconds. (It is possible to stop the recording at any time by setting the PAPER DRIVE toggle switch to "Stop").

(b) **Continuous Recording.**
The operator should follow the instruction outlined under (a), i.e. SINGLE CHART RECORDING except that to start the recording it is necessary to press the SINGLE CHART - CONTINUOUS RECORDING pushbutton and turn it clockwise. Recording will now automatically take place until the pushbutton is released again and the PAPER DRIVE, START-STOP toggle switch is set to "Stop".
Note: Whenever the PAPER DRIVE, START-STOP toggle switch is in the "Stop" position the paper drive is completely controlled by the SINGLE CHART - CONTINUOUS RECORDING pushbutton.

In order to synchronize the units, stop the paper so that the stylus rests on the 10 Hz line.
The pointer of the generator should now be set to the 1000 Hz REFERENCE SIGNAL mark on the frequency scale, and the SCANNING CONTROL SWITCH should be set to "Scanning On". The units should now be synchronized.
If the button marked 1000 Hz REF. SIGNAL is operated the Sine Random Generator will generate a signal of 1000 Hz enabling the operator to select a reference signal which is in the middle of the frequency range. (This ensures that when taking a recording of frequency characteristics, where the lowest attenuation is around 1000 Hz that the deflection of the stylus lies within the scale limits of the paper during the recording).

Continuous Recording with Ten Times Enlarged Paper Speed.
The following method is adopted: Set the "1 : 10 Synchronizing Gear Lever" to its inner position (released). The actual paper drive speed then corresponds to the large numbers, marked around the PAPER SPEED knob. Recording on frequency calibrated paper is not possible in this position.
The start and stop of the recording will in this case be completely controlled by means of the PAPER DRIVE, START-STOP toggle switch.

E. Automatic Regulation of the Output Power.

By means of the compressor circuit it is possible to regulate the output from the Sine-Random Generator. When a constant output voltage is required, the output voltage from the Generator is used as a control voltage. A constant current is obtainable if the voltage drop across a resistor connected in series with the load, is used as the control voltage, and a constant sound pressure is maintainable with the aid of a regulating microphone. The microphone is then placed in the sound field from a loudspeaker which is driven by the Generator and the microphone output voltage used as control voltage, see f.inst. Fig. 4.12 (it is essential that the frequency characteristic of the microphone is linear).

Proceed as follows:

1. Calibrate the Sine-Random Generator as described under Calibration, see under A.
2. Set the MATCHING IMPEDANCE switch to the desired position.
3. Connect the load to LOAD terminals or to the screened output socket at the top of the instrument, see B or C.
4. Feed the control voltage to the COMPRESSOR INPUT terminal. If necessary use an amplifier which has a linear frequency characteristic for amplification of the control signal, approximately 0.5 Volt being required for full utilization of the compressor.
5. Set COMPRESSOR VOLTAGE and OUTPUT LEVEL to maximum (fully clockwise).
6. Feed the voltage to be measured to the recording instrument, e.g. the Level Recorder Type 2305.
7. Set the COMPRESSOR SPEED switch to one of the position: 3, 10, 30, 100, 300 or 1000 dB/sec, see Appendix B.
8. Regulate the desired output voltage by turning COMPRESSOR VOLTAGE knob counterclockwise.

Note: When the Sine-Random Generator is used in conjunction with the Level Recorder Type 2305 the writing speed of the Level Recorder should be kept below the regulation speed of the compressor. It is also possible to obtain different regulation characteristics dependent on the position of the potentiometer marked OUTPUT LEVEL. This can be seen from Fig. 1.3.

Synchronization of the Sine-Random Generator Type 1024, the Level Recorder Type 2305 and the Audio Frequency Spectrometer Type 2112.

When the Sine-Random Generator Type 1024, the Level Recorder Type 2305 and the Audio Frequency Spectrometer Type 2112 are used in a measuring arrangement, interconnections must be made via Control Cable AQ 0002 for remote control from Level Recorder to Spectrometer and a Flexible Shaft UB 0041 for the mechanical tuning arrangement for Sine-Random Generator. The logarithmic frequency scale of the Generator allows it to be completely synchronized with the Spectrometer.

Synchronization.
To fully synchronize the three units the following sequence of operation is recommended. Switch on the power for each instrument and connect the RECORDER terminal of the Spectrometer to the INPUT terminal of the Level Recorder, then calibrate as follows:

The Generator Section.
Calibrate the Sine-Random Generator as in "Calibration of the Frequency Scale".

Spectrometer.

1. The control knobs should be set as follows:—

INPUT SWITCH:	"Direct"
METER RANGE:	"Ref."
METER SWITCH:	"Fast", "RMS"
RANGE MULTIPLIER:	"× 1, 0 dB"
FUNCTION SELECTOR:	"Linear, 2—40ooo Hz"

   Control knobs not mentioned may be in any position.
2. The meter should now show a deflection to the red mark on the scale. Possible deviations being corrected by the screwdriver operated potentiometer marked SENSITIVITY — AMPLIFIER INPUT on the front panel.

Level Recorder.
(Note: In this case a 50 dB potentiometer is used. For other ranges refer manual for Level Recorder Type 2305).
Set control knobs to the following positions:—

1. POTENTIOMETER RANGE dB to "50".
2. RECTIFIER RESPONSE to "RMS".
3. LOWER LIMITING FREQUENCY to "20".
4. WRITING SPEED:
   50 mm paper: 250 mm/sec. (large figures).
   100 mm paper: 500 mm/sec. (small figures).
5. PAPER DRIVE to "Stop" and "Forward" positions.
6. MOTOR to "On".
7. Insert the desired type of frequency calibrated paper. (If necessary refer Level Recorder Manual).
8. Set INPUT ATTENUATOR to "10".
9. Using the INPUT POTENTIOMETER adjust stylus to full deflection — 4 dB (e.g. using 50 dB Range it will be 50 dB — 4 dB = 46 dB).
10. Pull the Synchronizing Gear Lever (1 : 10) marked "X" in Fig. 3.3 to outer position.
11. With a screwdriver turn the screw "S" in Fig. 3.3 until marking cut is in vertical position.

12. Set the PAPER SPEED to 10 mm/sec. (small figures). The spring loaded knob is operated by lifting, turning and dropping to correct position.
13. The toggle switch PAPER DRIVE is set to "start" whereby the paper should start moving. If not, press the pushbutton SINGLE CHART — CONTINUOUS RECORDING and release it again, the paper will move and after a chart length or less automatically stop.
14. Move the recording paper by means of the finger wheel "Z" shown in Fig. 3.3 until stylus rests on 10 Hz line.

At this stage final synchronization of the units takes place by first synchronizing the Spectrometer and Level Recorder sections as follows:—

Set the control knobs of the Spectrometer to:—

1. FUNCTION SELECTOR to "1/3 Octave — 0 dB".
2. FILTER SWITCH to one step before (counterclockwise) the position "12.5".
3. AUTOMATIC SWITCHING to "On".

Then the control knobs of the Level Recorder to:—

1. PAPER DRIVE to "Stop".
2. Press pushbutton marked SINGLE CHART and hold it. (Paper will move and the reference voltage commences to record). Release pushbutton when paper has moved to about the "200" Hz line.
3. Units are correctly synchronized when switching from the 80 Hz to the 100 Hz filter takes place on the 90 Hz line.
4. As a means to see how far the paper has to be shifted, it is recommended to draw a line, by means of the "100 mV Ref." button on the front plate of the Recorder, at the point where the paper has stopped. By using this line as a reference the paper can be shifted the appropriate distance to give correct synchronization.
5. To check the synchronization, run the recording until the pen is stopped on for example the 2000 Hz line. When correctly synchronized, the switching of the 800 Hz to the 1000 Hz filter should now take place at the 900 Hz line. If this is not the case repeat from item 2.
6. Finally reset the Writing Speed on 250 mm or lower if the large figures are being used, and to a figure of 500 mm or less if using the small figures.

To complete the synchronization sequence the Sine-Random Generator Type 1024 must be synchronized with the frequency calibration on the paper.

1. Set the SCANNING CONTROL SWITCH to "Scanning On".
2. Rotate main scale of the Generator manually until it corresponds to the frequency denoted by the stylus, firstly moving it to a higher frequency and then rotating it back until it arrives on the desired frequency. This will take up any possible backlash in the gears of the instrument.

All units should now be in complete synchronization and when switching the toggle switch of the PAPER DRIVE on the Recorder to "Start", the combination will operate in complete unison.

Partial Blocking of the Frequency Range.

When the Sine-Random Generator is switched to supply a sine-wave or narrow band noise signal the frequency range is, as previously mentioned, from 20 to 20000 Hz. If the capacitor is set to frequencies above 20000 Hz or below 20 Hz the variable-μ amplifier can be blocked and consequently no output voltage will be obtained. In cases where the Generator is used in combination with the Level Recorder Type 2305, this is a great advantage as no unwanted curves will then appear on the corresponding section of the frequency calibrated paper.

The cut-off section can be made wider by adjusting the cam discs, connected to the rear end of the capacitor spindle. However, if the REMOTE CONTROL plug is removed there will be no blocking at any part of the scale.

In applications where the generator is employed in conjunction with the B & K Level Recorder and where automatic recording is required, the blocking arrangement can also be used for remote lifting of the Level Recorder's writing pen.

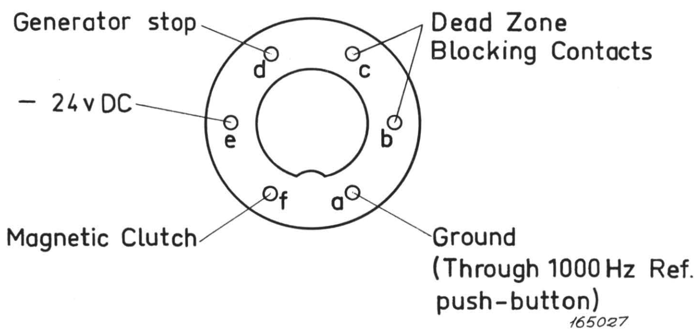

Fig. 3.4. REMOTE CONTROL socket, viewed internally.

Remote Control.

In the main description of the apparatus several forms of remote controls are mentioned. To carry out any of these use must be made of the REMOTE CONTROL jack on the front panel, the appropriate connections being made to the pins of the six-pin socket. Fig. 3.4 shows the different pins on the socket.

Remote Control of the magnetic clutch can be obtained by making or breaking a connection between e and f, providing the SCANNING CONTROL SWITCH is set to "Scanning Off".

For remote interruption of the output signal the terminal d should be connected to terminal a (ground). This arrangement is used, for instance, when reverberation measurements are carried out automatically by employing the B & K Level Recorder Type 2305. A special switch in the Recorder then connects terminal d to ground when the sound has to be interrupted.
Terminal b and c are in connection with an internal contact used for interrupting the signal output when the frequency scale pointer is outside the scale.
Note: When delivered from the factory, each Generator is supplied with a 6 poled plug JP 4725 containing the necessary connections for the function of the internal contact.

4. Applications

Measurement of the Frequency Response of Four-Terminal Networks.

The object to be tested e.g. a filter, transmission line, transformer etc. is connected to the output of the Sine-Random Generator Type 1024 switched to the Sine-Wave or Narrow Band Noise conditions, Fig. 4.1. Then point-by-point measurements can be taken by means of an electronic voltmeter. When the test signal is sinusoidal one of the B & K Voltmeters Type 2409, 2410, 2603 or 2604 should be used. However, when the test signal consists of narrow

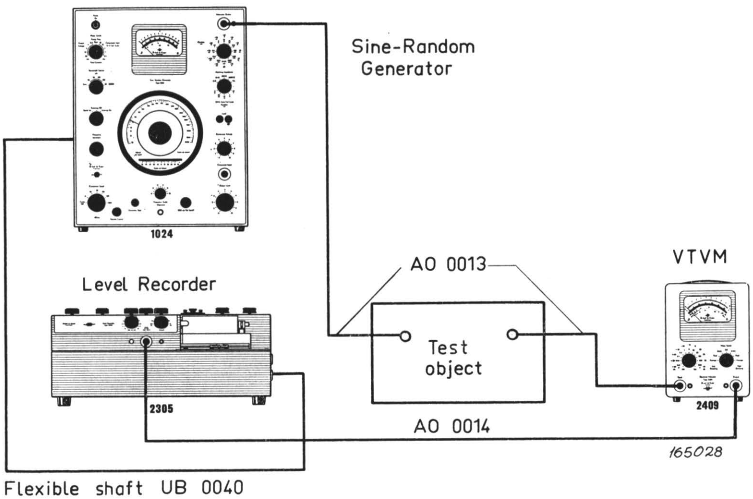

Fig. 4.1. Measurement of the frequency response of a four-terminal network. When Narrow Band Noise is used for the test use of the Random Noise Voltmeter Type 2417 in the read out circuit is advantageous.

band noise it is a great advantage to use the Random Noise Voltmeter Type 2417 which has been especially designad for this purpose. If it is desired to automatically record the frequency response the Level Recorder Type 2305 should be used as indicating instrument.

The mechanical coupling between the motor in the Level Recorder and the tuning capacitor of the Generator is effected with a Flexible Shaft UB 0041 and if it is desired to keep f.inst. the input current to the four-terminal network constant with frequency a compressor loop can be employed. In the latter case it is advisable to verify that the voltage at the COMPRESSOR INPUT is at least the required 0.5 Volt, which can be done by setting the METER SWITCH to "Compressor Input" position. The response of the network can then be recorded automatically on the Level Recorder Type 2305 Fig. 4.2.

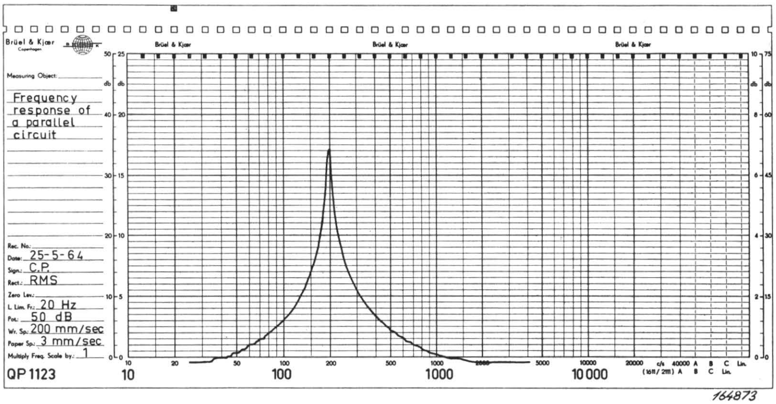

Fig. 4.2. Frequency Response of a four-terminal network.

AC Bridge Measurements.
By employing the Sine-Random Generator Type 1024 and a Frequency Analyzer Type 2107 as an indicating instrument selective measurements of components in an AC bridge can be obtained.
The only requirement the bridge must satisfy is that one diagonal point can be grounded as shown in Fig. 4.3. This requires the bridge to be supplied from the Generator via a screened transformer e.g. TU 0005, the Generator being grounded at one terminal.

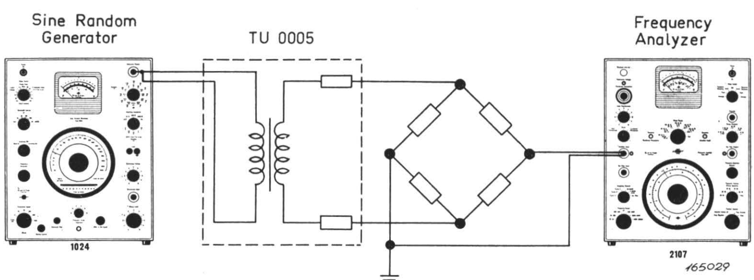

Fig. 4.3. The Sine-Random Generator Type 1024 used as a voltage source for AC Bridge Measurements. The Output Transformer TU 0005 provides a symmetrical output from the Generator.

Due to the selectivity of the Frequency Analyzer it is well-suited as an indicating instrument in a bridge circuit. Also the decibel scale on the instrument meter will often prove useful when it is desired to measure the quality of different components placed within the bridge.

Measurement of Gain in A.F. Amplifiers.

Frequently it is important to check the linearity of an amplifier i.e. to measure the gain for different values of input voltage. As the attenuator circuit of the Sine-Random Generator Type 1024 is very accurately calibrated it is an extremely useful instrument in carrying out gain measurements. In this case, the instrument should be switched to its sine-wave condition.

The output voltage from the amplifier under test should be measured with an Audio Frequency Voltmeter Type 2409 (or 2410), or a Microphone Amplifier Type 2603 (or Type 2604) an example of the arrangement being given in Fig. 4.4.

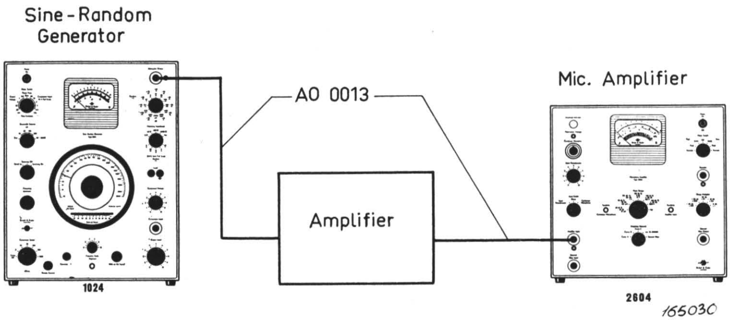

Fig. 4.4. Measurement of gain in an AF amplifier.

Frequency Response Recording of Loudspeakers.

The Sine-Random Generator Type 1024 is especially well suited for measurements on loudspeakers due to its dual sine-random outputs and its compressor circuit.

According to the I.E.C. Draft Recommendation a loudspeaker should be tested by means of pure tones, and under free-field conditions (e.g. in an anechoic chamber). The loudspeaker under test should be driven with a constant voltage or current, the latter producing a mechanical force of constant amplitude which is applied to the diaphragm. A constant current can be obtained in the circuit when the voltage across a series resistor is fed to the compressor amplifier in the Sine-Random Generator.

The sound pressure level produced by the loudspeaker is then measured by means of a microphone the output signal of which is fed to the Level Recorder via a Microphone Amplifier, see Fig. 4.5.

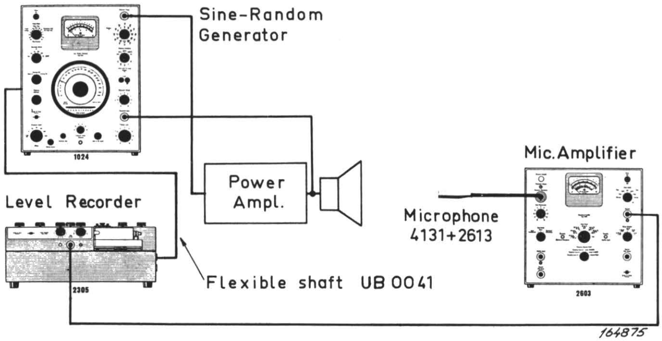

Fig. 4.5. Measuring arrangement used for recording the frequency characteristic of a loudspeaker.

In the I.E.C. Draft Recommendation it is also specified that the power handling capacity of a loudspeaker shall be tested by means of a noise signal in a room of not less than 8 m^3. This type of loudspeaker test can also be carried out by means of the Sine-Random Generator Type 1024. From the generator the noise signal must be fed to a power amplifier the output terminals of which are connected to a low-pass filter. The specification of this filter is given in the I.E.C. Draft Recommendation. To pick-up the acoustical signal from the loudspeaker, a measuring set-up as described for frequency response recording can be used.
To obtain an estimation of the quality of a loudspeaker used in an ordinary room, the test source can be a narrow band of random noise sweeping in the frequency range from 20 Hz to 20000 Hz. The Sine-Random Generator Type 1024 produces such a signal. With a narrow band noise as test signal, the operation of the loudspeaker may be similar to normal conditions. When testing loudspeakers the use of a band of random noise is effective in smoothing out the sharp peaks and valleys introduced into the response curves by the room during indoor measurements, while the "basic" response is retained.

Recording of the Frequency Response of Microphones.

Fig. 4.6 shows a typical arrangement for automatically recording the frequency response of a microphone.

In the set-up shown, the microphone to be tested is connected to the Level Recorder Type 2305, via a Microphone Amplifier Type 2604, the originating sound source being a loudspeaker which is fed from the Sine-Random Generator Type 1024 switched to operate as a sine-wave generator. As the sound pressure in front of the microphone under test has to be kept constant, it is necessary to place it relatively close to another microphone (in this case a Condenser Microphone Type 4131) which is coupled to a second

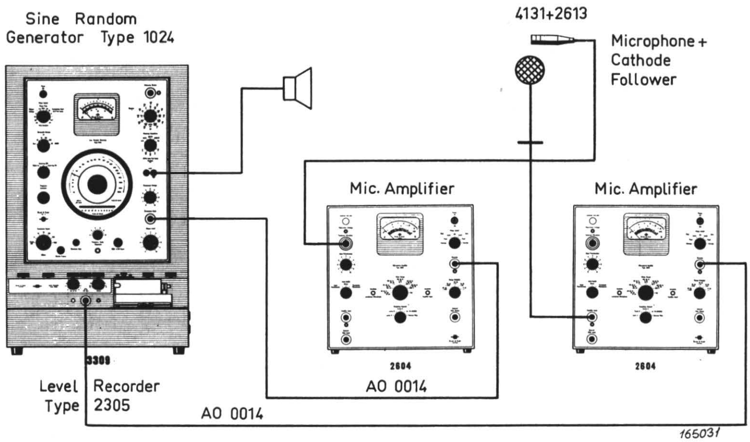

Fig. 4.6. Measuring set-up for automatic recording of the frequency response of microphones.

Microphone Amplifier Type 2604, the output of which is fed to the COMPRESSOR INPUT of the Generator ensuring a constant sound source. It is essential that the two microphones are symmetrically placed in the radiated sound field and the correct compressor speed selected. The acoustical delay time required for the sound to travel from the loudspeaker to the microphone must be small in comparison to the time constant determining the compressor speed. Under normal circumstances these conditions are easily fulfilled.

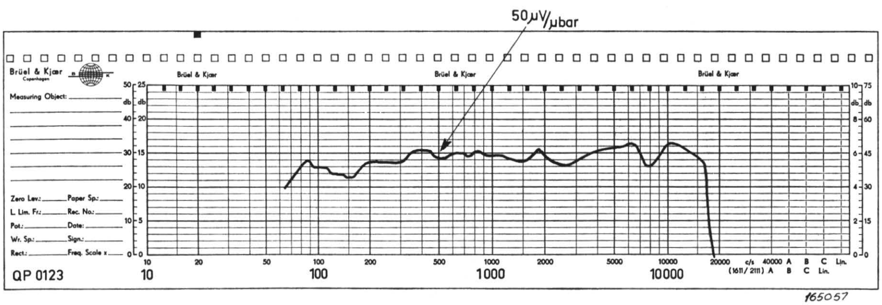

Fig. 4.7. Recording made with the set-up shown in Fig. 4.6.

To give reliable measurements the room to be used need not be fully anechoic as the regulating effect of the compressor will compensate for any minor reflections set up. However, for correct operation of the regulation circuit, the reverberation time of the room must not be too long and a low scanning speed should be used for the frequency sweep.

In Fig. 4.7 will be seen a recording showing the frequency response of a microphone recorded by employing the previously outlined system.

Recording the Frequency Characteristic of Earphones.

A recommended set-up for the testing of earphones is displayed in Fig. 4.8. By this method it is possible to automatically record the frequency characteristics of the components under well-defined acoustical conditions.

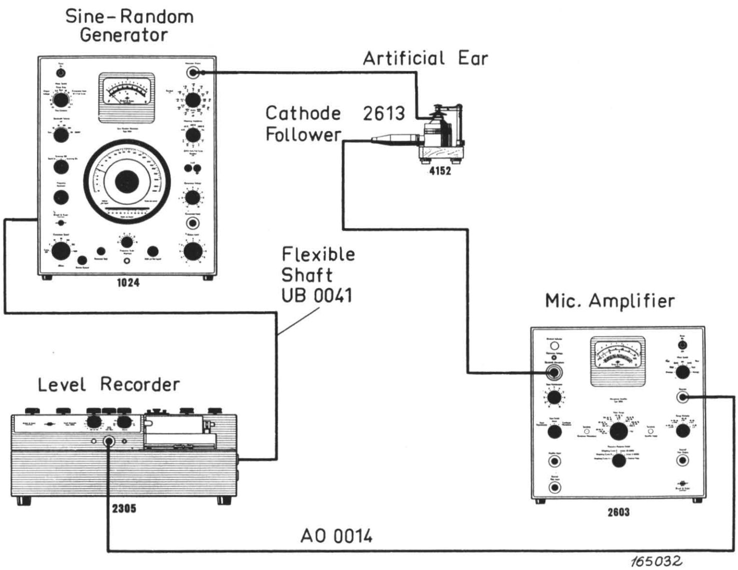

Fig. 4.8. Measuring arrangement for recording the frequency characteristic of earphones.

A sine-wave signal obtained from the Sine-Random Generator Type 1024 feeds the earphone under test which is placed in the Artificial Ear Type 4152. Different types of couplers are available for the Ear. A DB 0138 2 cm^3 which conforms to ASA Z 24.9. 1949 and the new IEC standards is suitable for measurements on insert type of earphones. For headsets and similar external earphones a 6 cm^3 can be supplied e.g. DB 0160 (N.B.S. type) or DB 0161 (A.S.A. type).

A B & K Condenser Microphone 4132 is placed in the coupler and measures the S.P.L. produced by the earphone. The output from the Microphone is fed to the input of the Amplifier Type 2603 and the amplified signal fed to a Level Recorder Type 2305 to obtain a graphic recording, see also Fig. 4.9.

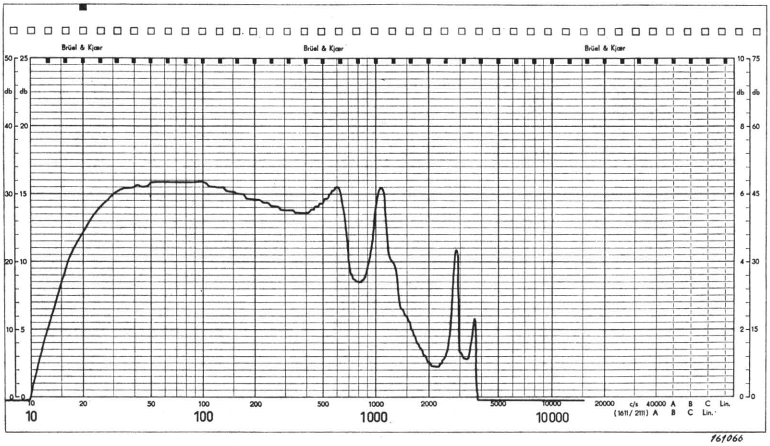

Fig. 4.9. Recording of the frequency characteristic of an earphone.

Checking of Hearing Aids.

An arrangement for the checking of Hearing Aids is illustrated in Fig. 4.10. This set-up makes it possible to automatically record the frequency characteristic of a complete hearing aid, under what are approximately free field conditions.

The hearing aid earphone under examination is placed on the Ear of the Hearing Aid Test Box Type 4212, which consists of an external Artificial Ear, a regulating microphone, and a built-in loudspeaker, the latter two of which are enclosed in a small anechoic chamber. The chamber is effectively insulated against both airborne and impact noise, allowing measurements to be taken down to 50 dB re. 2×10^{-4} μbar approximately.

The hearing aid and the regulating microphone are placed symmetrically in the sound field. The regulating microphone is connected to the Microphone Amplifier Type 2603, which amplifies the signal and then applies it to the Compressor input of the Sine-Random Generator Type 1024. This combination enables the sound pressure level on the hearing aid to be kept constant without influencing the practically free sound field conditions.

The Generator is set to supply a sine-wave signal to the loudspeaker in the chamber, while a B & K Condenser Microphone, which is placed in the Artificial Ear, is used for the measurement of the acoustic output from the hearing aid. The microphone is connected to a Microphone Amplifier Type

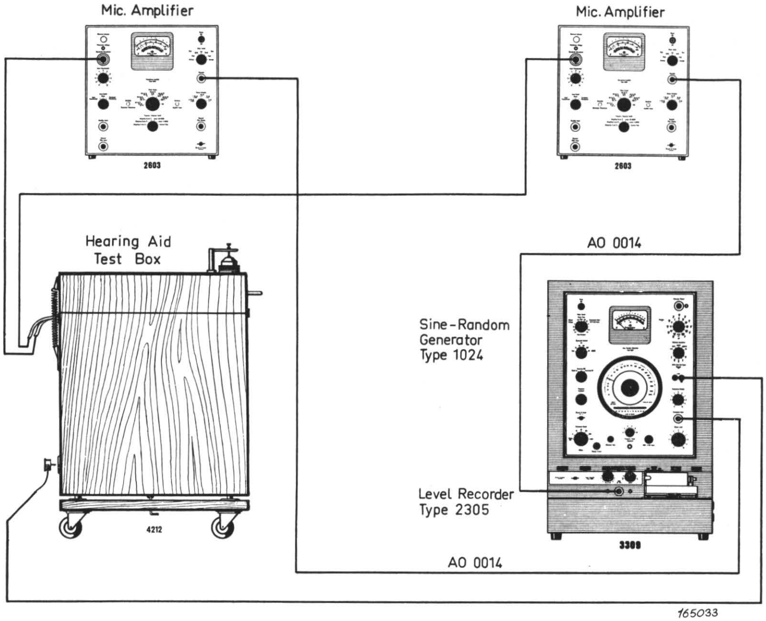

Fig. 4.10. Arrangement for automatically checking the frequency characteristic of a hearing aid.

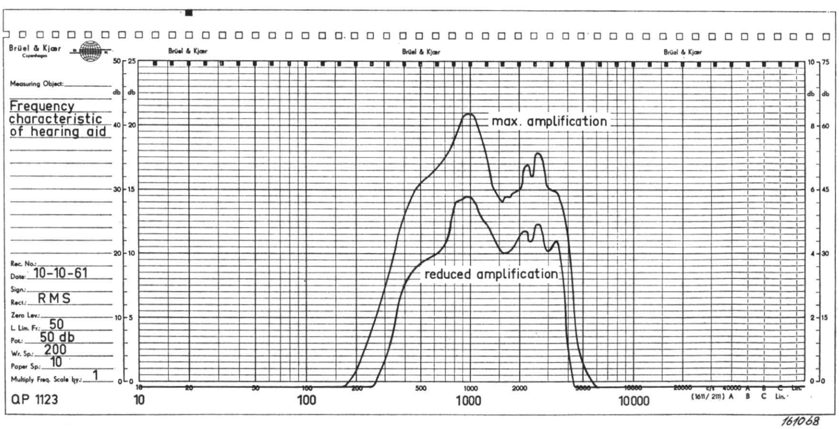

Fig. 4.11. Recording obtained from the set-up shown in Fig. 4.10 for two different settings of the hearing aid volume control.

2603, and the amplified voltage is led to the input of a Level Recorder Type 2305.
Fig. 4.11 shows typical characteristics of a hearing aid device automatically recorded with the arrangement described in 4.10. (Note: Recordings are taken for two different settings of the hearing aid volume control).

Measurements on Non-Linear System.
Wherever acoustic measurements are to be made on equipment designed for

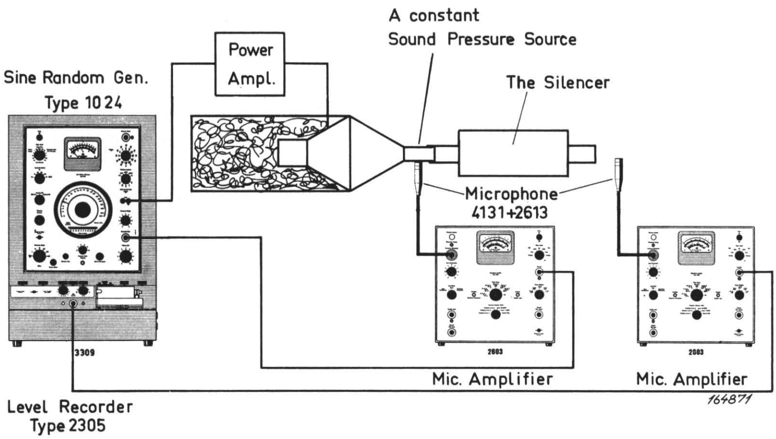

Fig. 4.12. A set-up used for measurements on silencers.

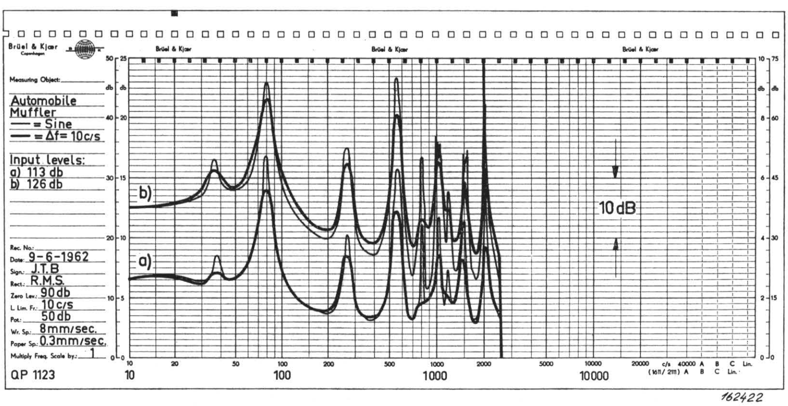

Fig. 4.13. Output sound pressure vs. frequency curves with constant input level on the silencer.
a) with sinusoidal input b) with a sweeping band of noise input.

operation in complex sound fields, and where non-linearities are present, bands of random noise should be used as test signals.
As an example a measuring set-up used for testing silencers is shown in Fig. 4.12. Narrow Bands of Random Noise are fed to a sound pressure source which is mechanically connected to the silencer. A compressor microphone and amplifier keeps the sound pressure level constant at the input to the silencer, and by means of another microphone and amplifier, the output signal from the silencer is recorded on the Level Recorder Type 2305.
In Fig. 4.13 are shown frequency response curves with various inputs to the silencer.

Airborne Sound Insulation Measurements.
A typical measuring set-up for the measurement of sound insulation is shown in Fig. 4.14. The necessary signal power is generated by the Sine-Random Generator Type 1024, which should be switched to the narrow band noise condition.
By measuring the different pressure levels in the two rooms alternately and recording the result automatically on the Level Recorder a curve as shown in Fig. 4.15 is obtained. The insulation can then be calculated directly from the recording, when the sound absorption of the receiving room is taken into account.

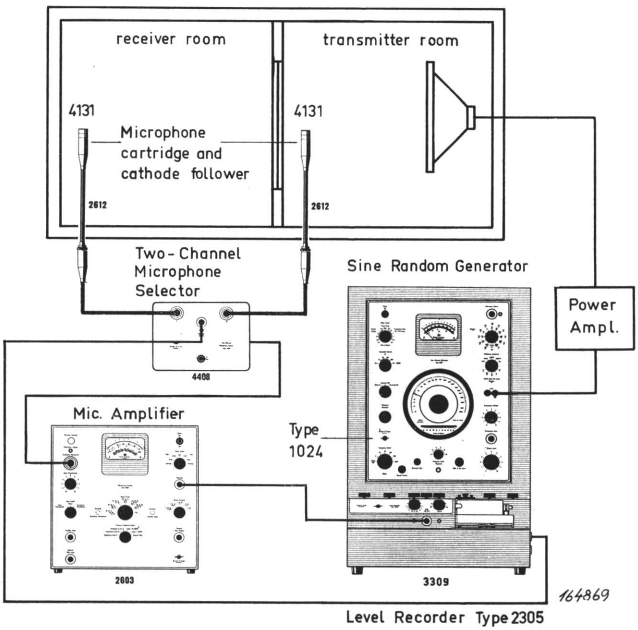

Fig. 4.14. Measuring set-up for sound insulation measurements.

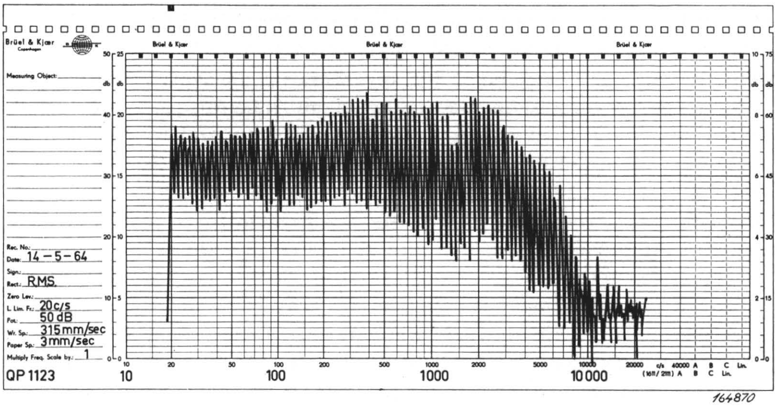

Fig. 4.15. Recording obtained with a measuring set-up as shown in Fig. 4.14.

Measurement of Reverberation Time.

One of the most important factors in determining the acoustic qualities of a room is the measurement of its reverberation time. The Sine-Random Generator is very well suited for this type of measurement.

The narrow band of random noise ensures that a great number of eigentones are excited simultaneously around the measurement frequency. The resultant recorded decay curves will in this manner appear with a smooth slope. That

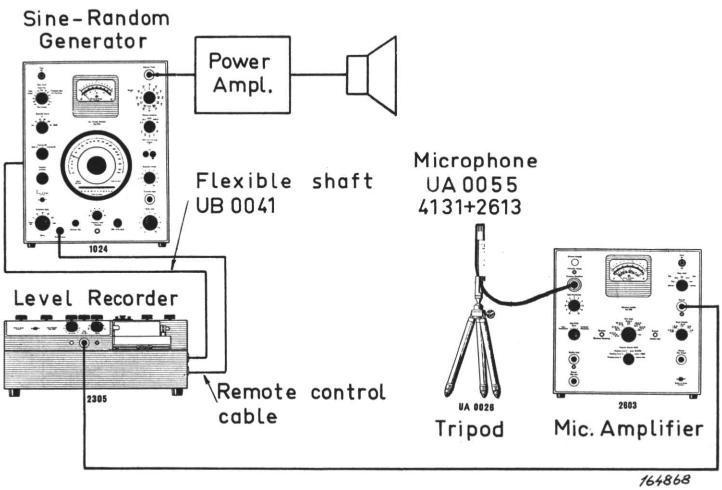

Fig. 4.16. Measuring equipment for the automatic recording of reverberation time.

would not be the case when a pure sine-wave signal is radiated in the room, as distinct standing waves would arise.

Various measuring arrangement for reverberation measurements can be set up where the Sine-Random Generator is an integral part. Here will be discussed an arrangement which works automatically and where the measured decays are recorded by the B & K Level Recorder Type 2305. The set-up is illustrated in Fig. 4.16. The Generator and the loudspeaker constitute the transmitting part, whereas one of the B & K Condenser Microphones, the Microphone Amplifier Type 2603 and the Level Recorder Type 2305 make up the receiving part.

The measuring arrangement shown allows decay curves of the reverberation to be recorded automatically throughout the frequency range 20 Hz to 20ooo Hz. If a frequency spacing of 1/3 octave is chosen in the measurements all the decays can be registered on the freuency calibrated part of a recording paper. If other spacing between the individual decay curves is required, the recording has to be made on non-frequency calibrated paper. Given below is a brief description of the principal working of the two types of measurements.

Frequency Calibrated Paper. For recording the decay of the sound in the room the sound source has to be disconnected at definite intervals, this is achieved by stopping the Generator. To ensure that only the part of the measurement is recorded which is of interest, the writing pen should lift from the paper in the interval between two decays. The disconnecting of the sound source and the lifting of the pen can all be automatically controlled by a special switch in the Level Recorder. (The Two-Channel Selector). The necessary connections between the different instruments are shown in Fig. 4.17.

When placing a loop of 50 mm paper width (Fig. 4.18) in the Level Recorder with a length of 495 mm (i.e. two chart lengths minus 5 mm; 5 mm being the distance between two perforated holes) it is possible to have the curves for the different frequencies placed with a spacing of 1/3 octave. By syn-

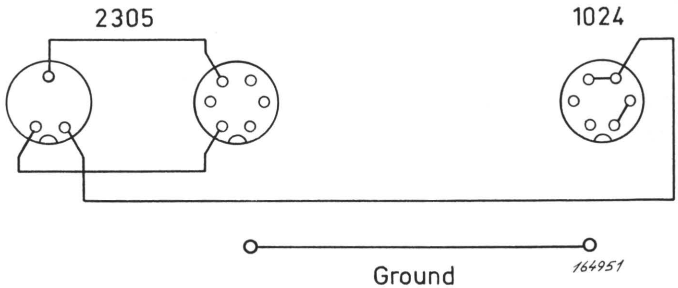

Fig. 4.17. Connections between the instruments. Internal view of the jacks.

chronizing the paper movement with the frequency scanning of the Sine-Random Generator and with the switching off moment of the sound, the starting points of the decay curves will correspond to the small squares on the top of the preprint of the recording paper QP 0423. It is possible, to a certain degree, to keep the sound pressure level at the point of measurement independent of loudspeaker and room response by utilizing the compressor circuit of the Generator. This method ensures that all the decay curves commence at the same level on the recording paper.

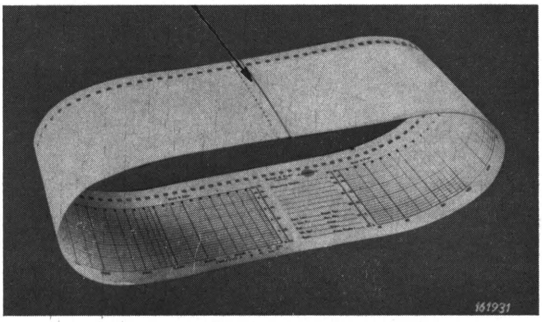

Fig. 4.18. Making up of paper loop.

Non-Frequency Calibrated Paper. When a spacing larger than 5 mm between the decay curves is desired, the recording paper loop used in the Recorder has to be made accordingly shorter as the length of this determines the spacing. For example, a loop length of 490 mm gives 10 mm spacing between the curves. In such instances the recording should be carried out on the lined recording paper, e.g. QP 0402, and it is necessary to "mark" one or more frequencies on the paper. The marking can be readily accomplished by means of the Level Recorder's EVENT-MARKER arrangement.
If only a few reverberation curves are to be taken, the situation may not warrant the use of automatic measuring, in these circumstances use should be made of the pressbutton marked GENERATOR STOP on the Sine-Random Generator. Also when it is desired to record the decay curves with a spacing less than 1/3 octave, the described function of the automatically working arrangement cannot be used immediately. The manually or remotely operated GENERATOR STOP may then be utilized.

Use of the Protractor SC 2361. The Protractor has been designed to facilitate the determination of reverberation time from recorded decay curves on the 50 mm paper width. It is divided into four sections marked "75 dB 10 mm/sec.", "75 dB 30 mm/sec.", "50 dB 10 mm/sec.", and "50 dB 30 mm/sec.".

When one of these four combinations of RANGE POTENTIOMETER and PAPER SPEED has been employed during the measurements, the reverberation time can be read directly in seconds.

1. The Protractor is held so that the printing is readable. The proper section is chosen and its left limiting line (thick diagonal) is placed on top of the portion of the recorded decay curve to be measured, and in such a manner that the centre of the Protractor coincides with one of the horizontal lines on the recorded paper. Refer Fig. 4.19.
2. Reverberation time in seconds is then read on the scale at the point through which the horizontal line passes.

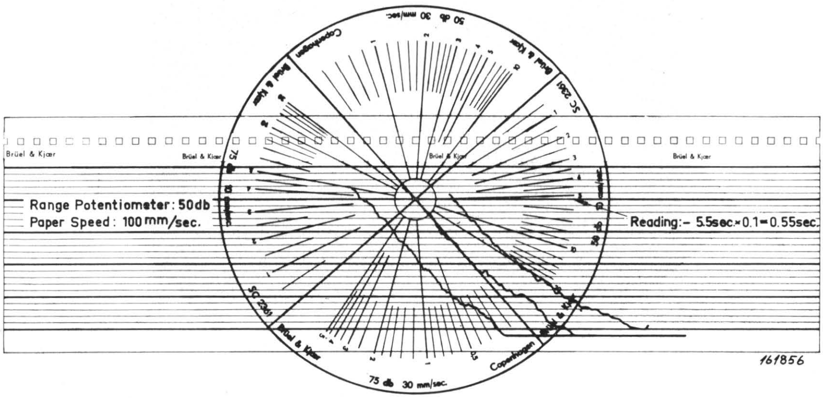

Fig. 4.19. Use of Protractor SC 2361. Ten times higher paper speed used than stated on the protractor "50 dB, 10 mm/sec". Reading then divided by 10, i.e. T = o.55 sec.

The decay curves should preferably be approximated into a straight line making it easier to determine the average slope.
If paper speeds other than 10 and 30 mm/sec. have been used, the determined reverberation times should be multiplied or divided by factors of 10.

Example.

50 dB Range Potentiometer.

Paper Speed 100 mm/sec: Use the section "50 dB 10 mm/sec." and divide the measured result by 10, see also Fig. 4.19.

Absorption Measurements on Sound Insulation Material.

The Sine-Random Generator Type 1024 in conjunction with the Standing Wave Apparatus Type 4002, enables the sound absorbing properties of different materials to be evaluated and their sound absorbent coefficients to be determined.
A set-up is shown in Fig. 4.20 where a sine-wave signal, produced by the Generator is fed to the loudspeaker which is mounted at one end of the

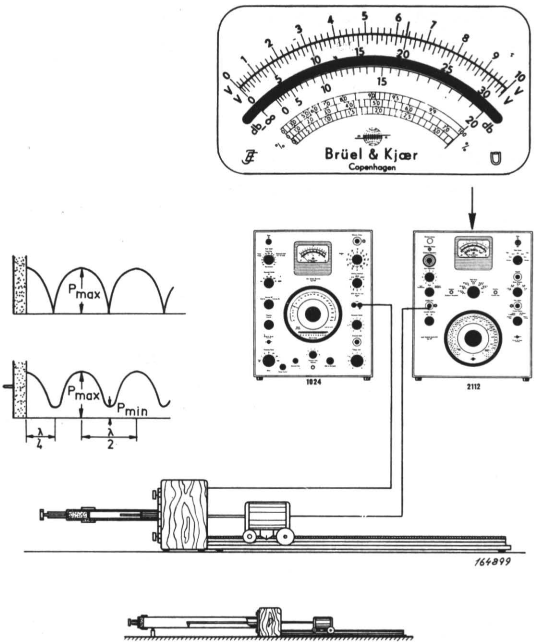

Fig. 4.20. Absorption measurements on sound insulating material by means of Standing Wave Apparatus Type 4002, Spectrometer Type 2112 and Sine-Random Generator Type 1024.

tube of the Standing Wave Apparatus Type 4002. Included in the apparatus is a probe type microphone which is mounted on a trolley, allowing the open end of the probe to be stationed at any point along the central axis of the tube. The output of the microphone unit is connected to the input of the Frequency Analyzer Type 2107 or the Audio Frequency Spectrometer Type 2112. The Analyzer Type 2107 can be continuously tuned through the band 20 to 20ooo Hz with a constant percentage bandwidth, the 3 dB bandwidth being variable in steps from 6 % to 29 %. On the other hand the Spectrometer 2112 has 33 1/3 octave and 11 1/1 octave filters with center frequencies from 25 Hz to 40 Hz, and 31.5 Hz to 31.5 kHz respectively. Both equipments have meter scales which directly indicate the sound absorption coefficient.

The material to be tested is placed in the termination end of the Standing Wave Apparatus and when the set-up is operated, due to the sound reflection from the sample, standing waves are produced in the tube. If the termination of the tube was made to consist of a totally rigid material, a complete reflection of the sound wave with minima equal to zero would be obtained. On replacing the rigid termination with an absorbent material only part of the wave will be reflected and the minima will no longer be zero. Thus by measuring the ratio between the maximum and minimum sound pressures the absorption co-efficient of the sample for 0 degree incidence sound can be found.

Sound Distribution Measurements.
Sound distribution measurements can be carried out by connecting a gliding narrow band of random noise, produced by a Sine-Random Generator Type 1024, to a loudspeaker and measuring the sound pressure level at various places by means of a condenser microphone and associated amplifiers, see Fig. 4.21. The "gliding" of the signal is made possible by connecting the tuning mechanism of the Sine-Random Generator mechanically to a Level Recorder as indicated in the figure and to keep an approximately constant output sound pressure level, a compressor loop may be used. In this way the sound distribution in the room is obtained not only as a function of position but also as a function of frequency.

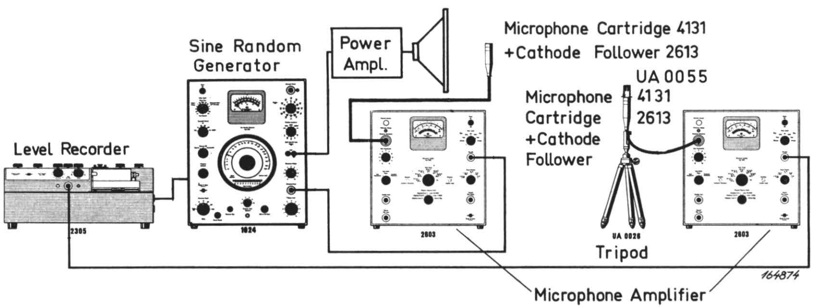

Fig. 4.21. Measuring arrangement for sound distribution analysis.

Appendix A.

Random Noise.

Random noise is defined as a signal, the instantaneous magnitude of which is not specified for any given instant of time. The instantaneous magnitudes of random noise can be described only by probability distribution functions which give the fraction Δt of the total time T that the magnitude x, or some

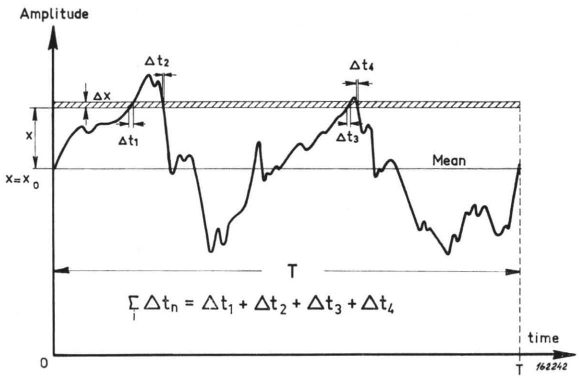

Fig. 5.1. Schematic illustration of probability.

sequence of magnitudes, lies within a specified range $(x + \Delta x) - x$, see Fig. 5.1. The time fraction, during which instantaneous magnitudes are present within x *and* $x + \Delta x$, is seen to be:

$$\Sigma t_n = \Delta t_1 + \Delta t_2 + \Delta t_3 + \Delta t_4$$

The probability P, that instantaneous magnitudes are present within the voltage limits x *and* $x + \Delta x$, will then be:

$$P\,(x; x + \Delta x) = \frac{\Sigma\, t_n}{T}$$

The probability is a dimensionless quantity which is independent of time, provided the time T is long enough to allow a practically "infinite" number of events to happen.

Since the magnitude of the signal is statistically distributed, it is convenient to introduce the concept of probability density ("amplitude density"). This gives the picture of the distribution of the instantaneous magnitude in the signal, because the magnitudes occur with a certain "density" when the phenomenon is studied over a period of time. From the probability $P(x, x + \Delta x)$ the probability density $p(x)$ can be derived:

$$p(x) = \lim_{\Delta x \to 0} \frac{P(x, x + \Delta x)}{\Delta x}$$

By varying the value x from $-\infty$ to $+\infty$ and plotting $p(x)$ as a function of x, the probability density curve for the signal in question is found, Fig. 5.2.

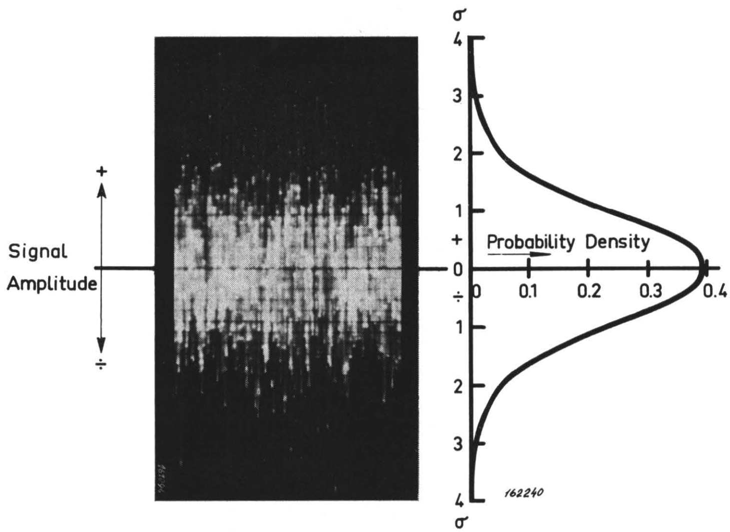

Fig. 5.2. Relationship between the magnitudes in a random noise signal and the probability density curve.

Gaussian Random Noise.

This is a random noise signal, the magnitudes of which are distributed

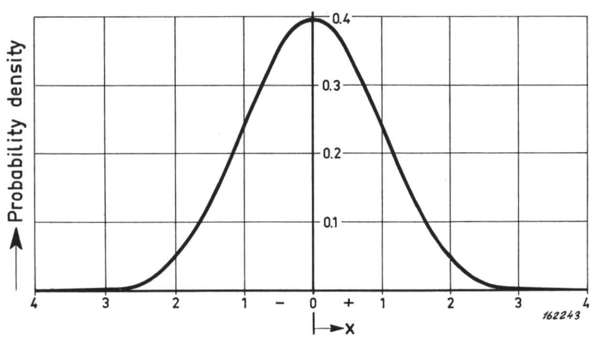

Fig. 5.3. Theoretical and normalized Gaussian probability density curve.

according to the Gaussian (normal) distribution function. The Gaussian distribution is based on an infinite number of events which have no correlation.
When the magnitudes in a noise signal are distributed in accordance with a Gaussian function, the probability density function *p (x)* will be:

$$p(x) = \frac{1}{\sigma \sqrt{2 \pi}} e^{-\frac{x^2}{2 \sigma^2}}$$

where σ is the standard deviation which equals the r.m.s. value of the noise signal. For the case $\sigma = 1$:

$$p(x) = \frac{1}{\sqrt{2 \pi}} e^{-\frac{x^2}{2}}$$

From this function the Gaussian probability density curve, illustrated in Fig. 5.3, is plotted.

Gaussian Random Noise with Uniform Spectrum Density.
This type of noise signal is a Gaussian random noise signal, the frequency spectrum of which is continuous and uniform, thus containing equal power per cycle bandwidth in the band considered. A noise signal which has a uniform spectrum density and is normally distributed will in many cases simulate the excitation that would be expected in environments determined by the laws of nature. It is therefore a powerful tool in research and development.

Narrow Band Gaussian Random Noise.
There are certain special characteristics of narrow band Gaussian random noise which should be pointed out. By "narrow band" is here meant a band of noise where the bandwidth is very small as compared with the band center frequency. Actually, looking at such a signal when it is displayed on the screen of an oscilloscope Fig. 5.4 some of these characteristics can be readily noted. It is for instance clearly seen that the signal looks like a modulated sine wave with a "carrier" frequency approximately equal to the center frequency of the band. Although it can not *so* easily be seen, the highest frequency of the "modulation signal" (envelope) is of the order of the noise signal bandwidth.

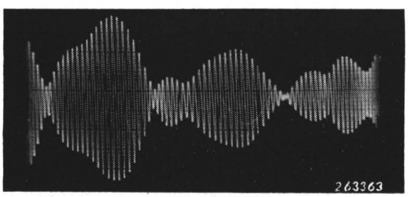

Fig. 5.4. Typical time record of narrow band random noise.

Furthermore, as long as a signal with a Gaussian distribution of the instantaneous values is passed through linear circuits, such as for instance a band pass filter, the instantaneous value distribution remains Gaussian. The instantaneous value distribution of the narrow band noise signals produced by the Sine-Random Generator is therefore also Gaussian.

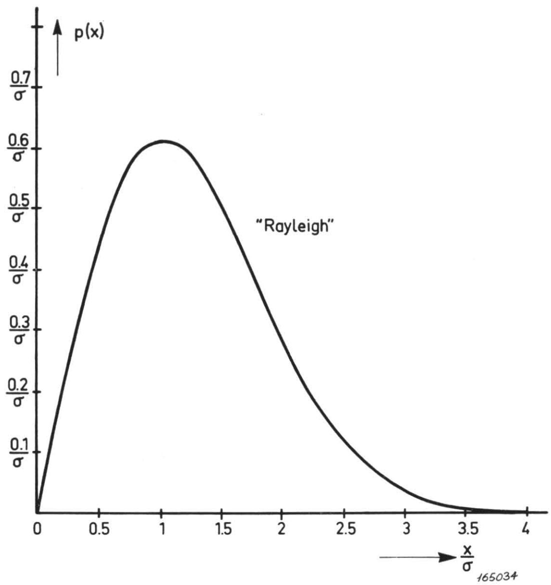

Fig. 5.5. The Rayleigh probability density function.

Finally, it is possible to uniquely describe the distribution of signal peaks. It can be shown theoretically (and experimentally) that the distribution of the narrow band signal peaks follows, very closely, the so-called Rayleigh distribution, Fig. 5.5.

These characteristics may be useful to remember as they make narrow bands of noise excellent test signals in a variety of applications.

Appendix B.

Use of the COMPRESSOR SPEED Switch.

By utilizing the compressor circuit in the 1024 Generator an automatic regulation of the output power is possible. If the compressor circuit is used in a closed loop servo control system the speed with which changes in the Generator output takes place is determined by the setting of the knob marked COMPRESSOR SPEED as mentioned in "The Regulating (Compressor) Amplifier" section. When the Generator is set-up to perform a sweeping sine-wave test the choice of COMPRESSOR SPEED depends largely on two factors:

a. The lowest frequency used. A very fast control system will at low frequencies be able to interact with the signal waveshape and thus introduce harmonic distortion. Consequently if distortion must be minimized, COMPRESSOR SPEED should not be set to higher values than stated in the Table given below:

Lowest Frequency of Chosen Sweep Range Hz	COMPRESSOR SPEED dB/sec.
20	10
30	30
100	100
300	300
1ooo	1ooo

b. The rate with which any system resonance builds up during scan. Obviously the system must be able to adjust itself faster than the frequency-response of the test object is changing.

When the scanning speed is low enough it is normally possible to satisfy both the conflicting requirements a and b by using one of the fixed compressor speeds.

On occasions when the narrow band noise condition of the Generator is utilized a too high Compressor speed will result in noise peak-clipping and the maximum values of compressor speed recommended in this case are:

"Narrow Random Bandwidth" c/s	Compressor Speed dB/sec.
10	3
30	10
100	30
300	100

Specification

Oscillator Section.

Three types of output are available from the oscillator:

1. Narrow Bands of Random Noise.
2. Sine-Waves.
3. Wide Band Random Noise.

1. **Narrow Bands of Random Noise.**

A narrow band of random noise can be swept automatically throughout the frequency range 20—20000 Hz. The frequency characteristic is better than ± 0.3 dB on ATTENUATOR OUTPUT and better than ± 0.5 dB on LOAD.

a. **Bandwidths.** Four different bandwidths can be selected. The "shape" of the noise bands are tabulated below.

Attenuation vs. Frequency Characteristics of the Noise Bands.

Frequency	Δf = 10 Hz	Δf = 30 Hz	Δf = 100 Hz	Δf = 300 Hz
$f_0 \pm \Delta f$	> 10 dB	> 20 dB	> 20 dB	> 20 dB
$f_0 \pm 2\,\Delta f$	> 20 dB	> 40 dB	> 40 dB	> 50 dB
$f_0 \pm 3\,\Delta f$	> 30 dB	> 50 dB	> 50 dB	> 60 dB

b. **Voltage Distribution.** Symmetrical Gaussian (normal) instantaneous voltage distribution up to four times the r.m.s. value (4 σ) at full output voltage.

c. **Outputs.** Switchable matching impedance for 6, 60, 600 or 6000 ohms load. Max. power output 0.25 watts approx. The attenuator is variable in steps of 10 dB (within ± 0.2 dB) from 40 μV to 4 V. The output voltage is continuously variable by potentiometer within each step. The signal to hum ratio is better than 70 dB.

d. **Frequency Scale.** 20—20000 Hz truly logarithmic. Accuracy 1 % ± 1 Hz.

Increment Scale — 50 to + 50 Hz of main scale reading. Both scales illuminated.

2. **Sine-Waves.**

Continuously tuneable within the frequency range 20—20000 Hz. The frequency characteristic is better than ± 0.3 dB on ATTENUATOR OUTPUT and better than ± 0.5 dB on LOAD 1 watt loaded.

a. **Output.** Switchable matching impedance for 6, 60, 600 or 6000 ohms load.
Max. power output 2.5 watts approx. Attenuator variable in steps of 10 dB (within ± 0.2 dB) from 125 μV to 12.5 V. The output voltage is continuously variable by potentiometer within each step. The signal to noise ratio is better than 65 dB at maximum output, the signal to hum ratio is better than 70 dB.

b. **Frequency Scale.** Main Scale truly logarithmic from 20 to 20000 Hz. Tolerance ± 0.7 degrees of theoretical logarithmic curve.
Increment Scale range from — 50 to + 50 Hz of main scale reading. Both scales illuminated.
Frequency accuracy of main scale 1 % ± 1 Hz and increment scale ± 0.5 Hz.

c. **Distortion.**

Frequency in Hz	20	200	2000	20000
ATTENUATOR terminal				
No load with 10 V output approx.	0.7 %	0.25 %	0.25 %	0.7 %
LOAD terminal				
(Loaded 1 watt)	1.2 %	0.5 %	0.5 %	1.2 %

3. **Wide Band Random Noise.**

a. **Frequency Spectrum.** Flat to within ± 1 dB in the range 20—20000 Hz.

b. **Output.** Switchable matching impedance for 6, 60, 600 or 6000 ohms load.
Max. power output 0.25 watt approx. The attenuator is variable in steps of 10 dB (within ± 0.2 dB) from 40 μV to 4 V. The output voltage is continuously variable by potentiometer within each step. Signal to hum ratio is better than 60 dB.

c. **Voltage Distribution.** Symmetrical Gaussian (normal) voltage distribution up to four times the r.m.s. value (4 σ) at full output voltage.

Compressor Section.

a. **Frequency Range.** Flat to within ± 0.3 dB from 20 to 20000 Hz.
b. **Dynamic Range.** 50 dB (40 dB is compressed to less than 2 dB). Required input signal for full regulation is 0.5 V r.m.s. approx.
c. **Input Impedance:** 25 kohms.
d. **Regulation Speed:** 3 — 10 — 30 — 100 — 300 and 1000 dB/sec. Selectable by means of a switch.

Meter Section.

a. **Signal Rectifier.** Quasi-r.m.s.
b. **Integration Times.** Five meter time constants selectable 0.3, 1, 3, 10 and 30 sec.
c. **Meter Scale and Circuit.** Illuminated mirrored scale. Accuracy of scale better than 1.5 %, accuracy of circuit better than 2 % of full-scale deflection. Perfectly safeguarded against overload.
d. **Indicating Meter.** Moving coil instrument.

Miscellaneous.

a. **Oscillator Stop.** Pushbutton Oscillator Stop for noiseless switching in reverberation measurements. Remote control available.

b. **Frequency Limit Controls.** Partial blocking of the frequency scale by means of built-in cam-discs.

c. **Frequency Scan.** Worm gear in oscillator permits variable capacitor to be driven from motor of Level Recorder Type 2305. Connection achieved by flexible shaft. Magnetic clutch for set and release of drive. Clutch can be remotely controlled. Accurate synchronization with Level Recorder Frequency Calibrated Paper.

Power. 100, 115, 127, 150, 220 and 240 V. 50—400 Hz. Consumption 80 W.

Dimensions and Weight:

Excl. dial and knobs	Height	Width	Depth	Weight
Type 1024A	48 cm 19″	38 cm 15″	20 cm 8″	20.2 kg
Type 1024B	50.5 cm 20″	40 cm 16″	27.3 cm 11″	
Type 1024C	53.2 cm 21″	48.2 cm 19″	20 cm 8″	

B K

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