2603

INSTRUCTIONS AND APPLICATIONS

Microphone Amplifier Type 2603

The instrument is designed for the amplification and measurement of small AC voltages. The total amplification is 100 dB. By means of a switch the built-in rectifier and meter circuit can be switched to measure either the arithmetic average, the true r.m.s. or the peak value of the input signal. The instrument also contains the internationally standardized weighting networks for sound level measurements. Connections for Condenser Microphone and Level Recorder.

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BB 2603

Microphone Amplifier
Type 2603

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Contents

0. Introduction

The Microphone Amplifier Type 2603 is a very versatile measuring instrument which, when used in conjunction with suitable transducers, can be employed in a great variety of fields. It may be used as a vacuum tube voltmeter, as a sound level meter, as a vibration meter, and, when supplied with external band pass filters such as Band Pass Filter Set Type 1612, also as a frequency analyzer. As the name implies, however, it may predominantly be used in conjunction with a condenser microphone and used for sound measurements. A brief summary of the most common but important terms concerning sound and vibration thus follows.

Vibration and Sound.

It is generally known that sound is a transmission of energy through solid, liquid or gaseous media in the form of vibrations. These vibrations constitute variations in pressure or position of the particles in the medium.
Sound may also be defined as the auditory sensation evoked when such vibrations, normally in air, impinge upon the ear. As an auditory sensation sound is limited to frequencies in the range from about 20 Hz to 20ooo Hz. Pressure fluctuations outside this range will not generally produce the sensation of sound.

The Decibel Scale.

Acoustical instruments for measuring pressure variations are usually calibrated in dB (decibel). A dB value is a measure of relative power, i.e. so many dB above a reference power level:—

$$dB = 10 \log \frac{P}{P_o}$$

where P_o is the reference and P is the actual power measured. However, the power transmitted by a sound wave is proportional to the square of the pressure variations so that we have

$$dB = 10 \log \frac{p^2}{p_o^2} = 20 \log \frac{p}{p_o}$$

where p_o is the reference pressure and p is the root mean square value of the pressure variations. When sound pressure is measurd in dB re o.0002 μbar with equal weight given to all frequencies it is termed *sound pressure level.*

The logarithmic scale has been found very convenient because of the large range of sound intensities that the human ear can handle. It can detect pressure variations as low as 0.0002 μbar and can also withstand levels higher than 200 μbar. This is a ratio of more than $10^6 : 1$ which on the logarithmic scale is represented by 120 dB.

In Table 0.1 are given some commonly encountered sound pressure levels in order to give a better appreciation of the dB scale.

Sound pressure in bar	Sound pressure level in dB		Environmental conditions
		140	
1 mbar	134 dB		Pain Threshold
		130	
			Pneumatic Chipper
		120	
100 μbar	114 dB		Loud automobile horn (dist. 1 m)
		110	
			Inside airliner (DC 6)
		100	
10 μbar	94 dB		Inside subway train (New York)
		90	
			Inside motor bus
		80	
1 μbar	74 dB		Average traffic on street corner
		70	
			Conversational speech
		60	
0.1 μbar	54 dB		Typical business office
		50	
			Living room, suburban area
		40	
0.01 μbar	34 dB		Library
		30	
			Bedroom at night
		20	
0.001 μbar	14 dB		Broadcasting studio
		10	
			Threshold of hearing
0.0002 μbar		0	

Table 0.1. Some commonly encountered sound pressure levels.

The Detection of Sound.

The human ear is a remarkably sensitive instrument for the detection of sound waves. Its response to a certain sound pressure level depends however upon the frequency of the sound. The sensitivity is greatest at 1000—6000 Hz and falls off both for higher and lower frequencies.

A set of so-called equal loudness contours is given in Fig. 0.2. The curves show the intensity levels in dB re 0.0002 μbar, which at various frequencies are judged by the average human being to sound equally loud. Other sets of equal loudness contours which deviate from these curves in certain respects have been published by various investigators but the curves shown in Fig. 0.2 have been recommended as standard by the International Organization for Standardization (ISO/R 226-1961 (E)).

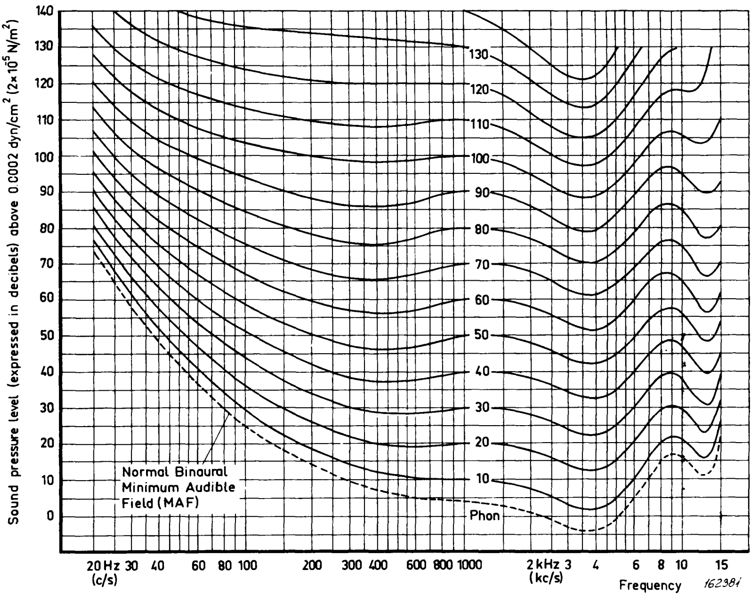


Fig. 0.2. Equal Loudness Contours.

The reference level is usually set up at 1000 Hz and the curves give the sound pressure level in dB necessary for a tone of a different frequency to sound equally loud. The loudness level is measured in phon and at 1000 Hz the phon value is equal to the dB value. It will be seen that the curves of constant phon become more and more straight as the loudness level is increased. At a level of 120 phon the ear is approximately equally sensitive to all frequencies in the audible range, while at 0 phon the variation in sound pressure level with frequency is great.

Although the response of the human ear depends on many other things beside frequency, modern sound level meters usually contain weighting networks in order to try and incorporate in the meter a frequency response similar to that of the human ear. Three different curves have been internationally agreed upon and standardized. These are referred to as the A, B

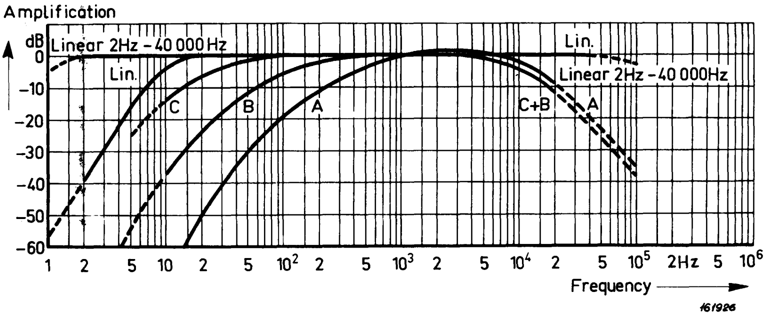


Fig. 0.3. Graph showing the response of the built-in weighting networks.

and C curves and are shown in Fig. 0.3. When sound pressure is measured using one of the weighting networks and quoted in dB re 0.0002 μbar it is termed *sound level.* The weighting network used should always be stated clearly e.g. if the sound level measured with the A weighting network is 70 dB, it should be quoted as 70 dB (A).

The Detection of Vibration.

A phenomenon which is closely related to what we usually think of as sound is vibrations in solid materials. Such vibrations are in most cases the source of sound and may have to be located in order to reduce their effect. (Noise control). Man's sensitivity to vibration is extremely limited, especially for the higher frequencies, so that measuring instruments are needed in order to determine accurately the vibrations in question. By substituting an accelerometer for the microphone, a sound level meter can usually be adapted to measure vibration instead of sound level and thus serve a dual purpose in the fight against excessive noise.

Vibration in a mechanical object is an oscillation related to certain reference conditions of the object. In vibration often three quantities are dealt with, displacement s, velocity v and acceleration a. The coherence between the three quantities are given in the following table. (For the sake of convenience the relationships are also given with respect to pure sinusoidal vibrations).

Given Quantity:—	Transferred to—		
	s	v	a
s $s = S_0 \sin(\omega t)$		$v = \frac{ds}{dt}$ $v = \omega S_0 \cos(\omega t)$	$a = \frac{d^2s}{dt^2}$ $a = -\omega^2 S_0 \sin(\omega t)$
v $v = V_0 \sin(\omega t)$	$s = \int vdt$ $s = -\frac{1}{\omega} V_0 \cos(\omega t)$		$a = \frac{dv}{dt}$ $a = \omega V_0 \cos(\omega t)$
a $a = A_0 \sin(\omega t)$	$s = \iint adt^2$ $s = -\frac{1}{\omega^2} A_0 \sin(\omega t)$	$v = \int adt$ $v = -\frac{1}{\omega} A_0 \cos(\omega t)$	

In the m.k.s. measuring system the units will be

s in m
v in m/sec.
a in m/sec.^{2}

Frequently a is expressed in the unit G which is the acceleration derived from the gravitational force of attraction of the earth. As the gravity alters with latitude and altitude a standard gravity is chosen to $G = 9.80665$ m/sec.^{2} = 32.1739 ft/sec.^{2}.

1. Description

General.

The Microphone Amplifier Type 2603 is primarily designed for acoustical, electroacoustical and vibration measurements.

Basically it consists of two independent amplifier sections which may either be connected in cascade or have a filter system interposed between them (see Fig. 1.1). The power supply contains the necessary rectifiers and filters for the operation of the amplifiers and can supply the external B & K Condenser Microphone or Preamplifier in use.

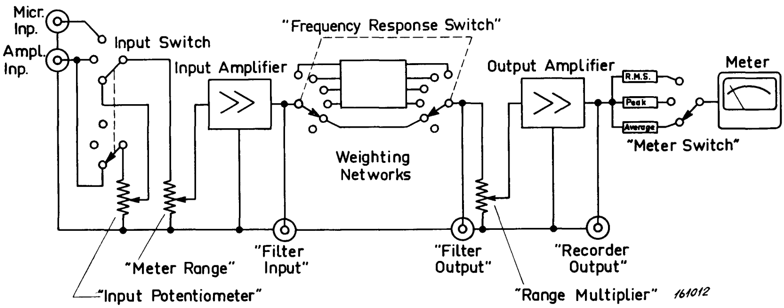


Fig. 1.1. Block diagram of the Microphone Amplifier.

The input and output amplifier sections can, as mentioned, be cascaded, this being accomplished by means of a switch on the front panel. By this means a high gain amplifier with a linear frequency characteristic in the range 2 Hz—40 kHz is obtained.

If a frequency analysis is required, external filters, such as the Band Pass Filter Set Type 1612 can be inserted between the amplifier sections. The set-up will then be identical to the Audio Frequency Spectrometer Type 2112.

In the case of vibration measurements the Preamplifier Type 1606 or Cathode Follower 2612, 2613, 2614 or 2615 with Accelerometers Type 4312 to 4315 can be connected to the CONDENSER MICROPHONE input of the Amplifier.

The switch on the front panel also enables a series of built-in weighting networks, which conform to IEC Standards, to be inserted between the amplifier sections. When using these built-in weighting networks in conjunction with the B & K Condenser Microphones Type 4131 and 4133 the specification matches that for a standard precision sound level meter.

Some of the main requirements in the IEC specification are quoted here:

A precision sound level meter shall include at least one of the three weighting networks called A, B or C, and should cover the frequency range 20 Hz to 20000 Hz within certain tolerances.

The microphone shall be of the omnidirectional pressure type. Permissible tolerances on the variation of sensitivity with angle are given, and it is suggested that the diffuse sound field sensitivity (i.e. the root-mean-square of the sensitivities for all orientations) should by some means be brought within the tolerances for the specified incidence.

A square law indication instrument is specified, i.e. it must be capable of correctly summing two pure tones according to the root-mean-square law.

Input Amplifier.

The two first stages of the amplifier consist of resistance-capacitance coupled triodes, while the third stage is built as a cathode-follower. A large amount of negative feed-back is introduced to stabilize the amplifier and to ensure a low source impedance of approximately 12 Ω, at the FILTER INPUT terminal. The heaters of the amplifier tubes are supplied from a stabilized DC supply. In this way a hum level lower than two microvolts, with reference to the grid of the input tube has been achieved. The use of specially selected tube types and coupling components also avoids disturbance from microphony in the amplifier, even when a signal of only a few microvolts is being measured.

The input amplifier is provided with two different input sockets, one of which is seven-poled and corresponds to the plug for the B & K Condenser Microphones and Preamplifiers. The other input socket accommodates a 14 mm coaxial plug and can be connected to the input circuit of the amplifier, either directly, or via a variable potentiometer for relative measurements. A three-position INPUT SWITCH marked "Condenser Microphone", "Direct", and "Input Potentiometer" gives individual selection of these three input facilities. When the INPUT SWITCH is selected to position "Condenser Microphone" the input socket marked CONDENSER MICROPHONE has to be used. In the other two instances the voltage to be measured should be fed into the AMPLIFIER INPUT socket.

From the INPUT SWITCH the signal voltage is fed to a voltage divider, which is operated by the knob marked METER RANGE on the front panel and contains five steps of 20 dB with a total impedance of 2.2 megohms. The different positions of the METER RANGE switch are marked for several values of input voltages between 10 mV and 1000 volts. A further position marked "Ref." serves to check the sensitivity of the instrument. With the METER RANGE switch in this position a square-wave type signal with the frequency of the mains is supplied to the grid of the input tube. The voltage is stabilized by a zener diode and will vary less than 0.3 % for a 10 % mains variation.

For the reason which follows, the calibration adjustment to the red mark on the instrument scale should be carried out with the METER SWITCH in position "RMS" and the FREQUENCY RESPONSE SWITCH set to "Linear

2—40000". With the FREQUENCY RESPONSE SWITCH in this position, the r.m.s. and the average value of the reference signal coincides with the red mark on the scale, while the peak value will be indicated by a 0.5—1 dB greater deflection. However, with the FREQUENCY RESPONSE SWITCH in position "Linear 20—40000" the r.m.s. calibration will still show a correct value, but the average and peak value will now deviate from this value. A deviation of up to 4 dB can be expected when the METER SWITCH is switched to "Peak". The deviation from the correct value of the peak and average values is mainly caused by phase distortion in the filter, which will be predominantly noticeable on peak measurements of complex signals that are just above the lower limiting frequency, see also Appendix.
The output of the input amplifier is paralleled by an OVERLOAD INDICATOR. The indicator is so designed that it gives a visual indication when signal peak voltages exceed 4.5 volts on the output of the input amplifier. The signal to be monitored is amplified in a triode connected pentode and fed to a gas tube, indicating overload by a red light. Refer also to item "Overdriving".

Output Amplifier.

Input Circuit. The output amplifier consists of three stages and shows an input impedance of 1.46 megohms.
In the input circuit a voltage divider is inserted, containing four steps of 10 dB and operated by the knob marked RANGE MULTIPLIER. With the RANGE MULTIPLIER switch in position "× 1 (0 dB)" the amplification of the output amplifier is 10 times. Maximum amplification is obtained with the RANGE MULTIPLIER switch in position "× 0.01 (—40 dB)" and is then 1000 times (60 dB).

Sensitivity Adjustment. The output amplifier is provided with negative feedback, the amount of which may be varied by two potentiometers. The sensitivity of the apparatus can then be adjusted and thereby calibrated, the reference voltage being used as calibration voltage. One of the potentiometers is in circuit when the INPUT SWITCH is in position "Condenser Microphone", the other when the switch is in either of the two positions "Direct" or "Input Potentiometer". Separate sensitivity adjustment is therefore obtainable for sound and voltage measurements, this being an additional convenience during practical use of the amplifier. The potentiometers can be adjusted with the aid of a screwdriver through holes in the front panel, which are marked SENSITIVITY — CONDENSER MICROPHONE and SENSITIVITY — AMPLIFIER INPUT.

Output. The output circuit of the amplifier is connected both to the output terminal marked RECORDER and to the rectifier and meter circuit. The RECORDER terminal is provided for connection to level recorder, headphones, oscilloscope, etc. Additionally it can be connected to the compressor input of the Beat Frequency Oscillator Type 1022. The output impedance at the terminal is 50 Ω.

The amplifiers are constructed in such a way that they do not clip the signal if its peak value, after amplification in the output stage, does not exceed a value of 13 dB higher than is indicated for full deflection on the meter, i.e. 10 volts + 13 dB = 45 volts peak. When the instrument meter gives full deflection, a voltage of 8—10 volts r.m.s. is available across the RECORDER terminals.

Rectifier and Meter Circuit.

A switch in the rectifier circuit marked METER SWITCH enables either the true r.m.s., the arithmetical average or half the peak-to-peak value of the input signal to be measured by the moving coil instrument.

R.M.S. Measurements. The characteristic current vs. voltage curve for an instrument which should measure the r.m.s. value, is a parabola. By means of a specially constructed circuit of resistors and semiconductor diodes this parabola is simulated. The rectifier circuit employed is a full-wave rectifier and the combined circuit is developed to measure the r.m.s. value of signals with crest factors f_c as high as 5,

$$f_c = \frac{S_{peak}}{S_{rms}} = 5.$$

However, due to the peak limiting (45 volts) of the output amplifier, the highest deflection for r.m.s. value of the meter pointer when measuring signals with crest factors 5, should not exceed:—

$$S_{rms} = \frac{S_{peak}}{f_c} = \frac{45}{5} = 9 \text{ volts}$$

For full deflection the crest factor f_c should not exceed:—

$$f_c = \frac{45}{10} = 4.5$$

At low frequencies the meter pointer will start to fluctuate when the METER SWITCH is in the position "Fast". When the fluctuation due to the low frequency is too large, the r.m.s. value read is no longer the correct value and the METER SWITCH should therefore be set in position "Slow". The lower limiting frequency in position "Fast" is approximately 20 Hz (sine wave).

Arithmetical Average Measurements. The circuit employed is a full-wave rectifier, enabling the average value of the complete signal to be measured. Care should be taken not to overdrive the amplifiers when measuring the average value of a complex signal which has high peaks. It is therefore necessary to know the highest peaks, positive or negative, which occur in the measured signal. By means of the two factors, crest factor f_c and form factor f_f, below

$$f_c = \frac{S_{peak}}{S_{rms}} \qquad\qquad f_f = \frac{S_{rms}}{S_{average}}$$

the peak value of the signal may be calculated, provided the average value (read on the meter) and the two factors are known.

$$S_{peak} = f_c \times f_f \times S_{average}$$

As the 45 volts peak should not be exceeded, when the meter pointer gives full deflection for average value, the highest permissible value for

$$f_c \times f_f = \frac{45}{10} = 4.5$$

If the meter pointer has not full deflection, the product $f_c \times f_f$ could be proportionally higher.

Peak Measurements. The circuits for measuring peak values is a normal full-wave rectifying circuit. The signal from the output amplifier is applied via a capacitor C_1, vide Fig. 1.2. Due to this capacitor the deflection on the meter corresponds to the half peak-to-peak value of the signal. This should be taken into account when the positive and negative values of a signal, applied from the output stage, are not equal. In such circumstances the peak value read on the meter is thus not the maximum that occurs. A further limitation of the peak indication is due to phase distortion in the amplifiers and is discussed in the Appendix.

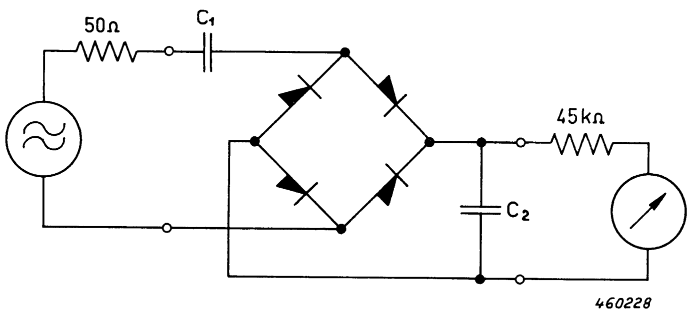


Fig. 1.2. Electrical circuit of peak rectifier.

As indicated in Fig. 1.2 the output resistance of the output stage is approximately 50 Ω, which is the charge resistance for C_1 and C_2. The discharge resistance for C_2 is approximately 45 kohms. Due to these finite quantities, signals with very sharp peaks and high crest factors will be somewhat clipped. The ideal case would be to use a zero charging resistance and an infinite discharging resistance which is, of course, impossible to realize in practice. However, even when measuring positive or negative pulses with crest factor 5 (refer passage "R.M.S. Measurements"), the clipping of the signal will be negligible. Fig. 1.3 gives an impression of a signal with a crest factor of 5.

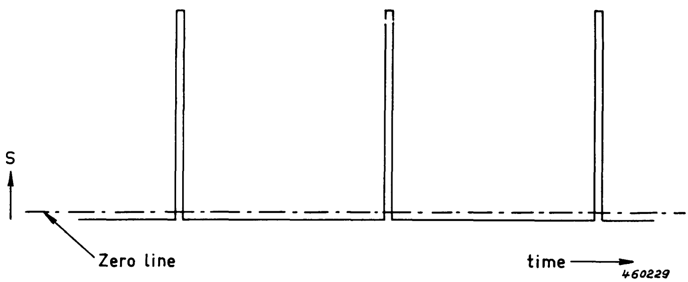


Fig. 1.3. Example of unsymmetrical signal with a crest factor of approximately 5.

At low frequencies, i.e. below 20 Hz (sine waves), the METER SWITCH should be set in position "Slow". The reason is as under "R.M.S. Measurements".

A description of the working principle of the complete rectifier circuit is given in the B & K Technical Review No. 3-1958.

Damping and Graduation of Meter.

The moving coil indicating instrument is furnished with two different damping characteristics "Fast" and "Slow" which are in accordance with the standards for sound level meters.

The meter is graduated 0—10 and 0—31.5 as well as 0 to 20 dB. In addition, scales permitting the direct reading of acoustic absorption coefficients are provided. These scales should be used when measurements are taken with the Standing Wave Apparatus Type 4002. When utilizing the first three graduations electrical measurements can be read either in mV, volts or in dB re 1 volt, and acoustical measurements in Sound Pressure Level (SPL) or Sound Level (SL) re 2×10^{-4} μbar. When measuring SPL or SL one of the B & K Microphones should be used in conjunction with the Amplifier. For use of the scales concerning the Standing Wave Apparatus, reference should be made to the Instruction Book for this apparatus.

Overall Performance of the Instrument.

Signal-to-Noise Ratio. When the RANGE MULTIPLIER switch is in position "× 1 (0 dB)", the signal-to-noise ratio for full scale deflection on the meter is better than 55 dB for any setting of the METER RANGE switch, see also Fig. 1.4. By using any of the other four positions of the RANGE MULTIPLIER switch, the signal-to-noise ratio for full meter deflection decreases by the same number of dB, corresponding to the increase in amplification. To obtain the best ratio between signal and noise voltage, the RANGE MULTIPLIER switch should thus, during measurements, be set to give as low amplification of the output amplifier as possible, preferably "× 1 (0 dB)".

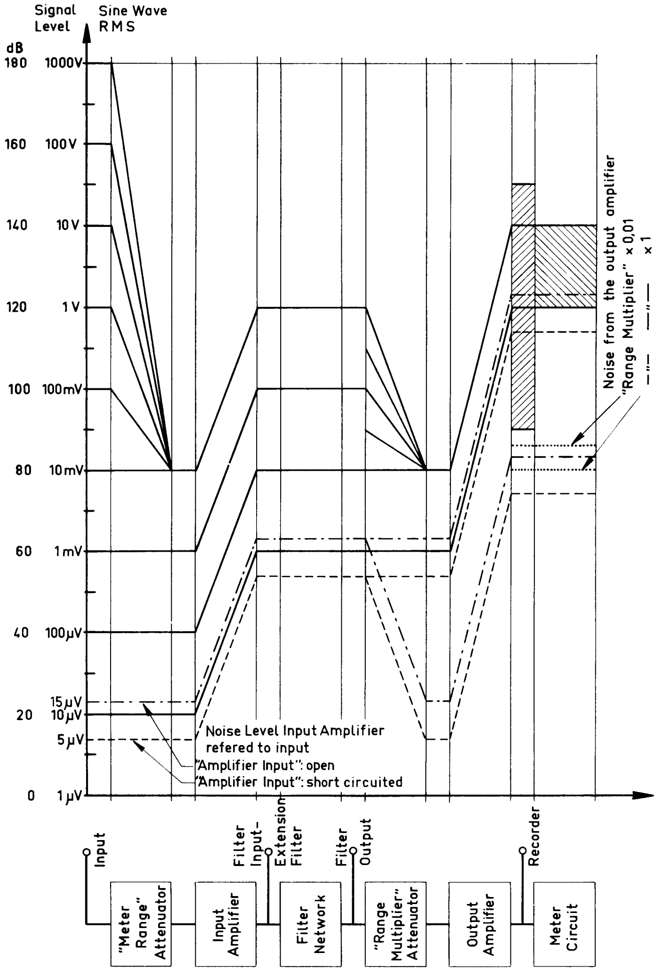


Fig. 1.4. Sketch showing the signal levels at different points in the Microphone Amplifier. The dotted lines indicate the noise levels.

Overdriving. When measurements are carried out where filters are inserted between the two amplifier sections, care must be taken not to overdrive the input amplifier. To allow possible overdriving of the input amplifier to be observed a visual indicator is connected in parallel to the output of the input amplifier, as previously described. The indicator lights up when signal peak voltages on this point exceeds 4.5 volts (3.16 volts r.m.s. sinewave) i.e. 10 dB higher than the 1 volt r.m.s. sine-wave, as required for o.1 % nonlinear distortion. The 4.5 volts peak voltage indication limits the measurements to signals with crest factor f_c lower than 4.5, which also is the highest crest factor allowable at full r.m.s. drive.

The higher peaks in the signal have to contain a certain energy to be indicated. When for example measurements are made on noise signals with Gaussian distribution the indicator will only react for noise peaks, which are lower than approximately 2.5 times the r.m.s. value, i.e. f_c lower than 2.5.

To be able to check on how far the input amplifier is driven in making selective measurements, the FREQUENCY RESPONSE switch of the Microphone Amplifier should first be set to position "Linear 2—40ooo" and RANGE MULTIPLIER to "× 1 (0 dB)". The r.m.s., average or peak drive of the amplifier can then be read on the indicating meter. Full deflection corresponds to 1 volt on the output of the input amplifier. From the above can be seen, that *in selective measurements, where the input amplifier is driven to maximum, the sensitivity of the Microphone Amplifier can only be increased by RANGE MULTIPLIER.*

Frequency and Phase Response. For the Microphone Amplifier with the FREQUENCY RESPONSE SWITCH in position "Linear 2—40ooo", typical frequency and phase response curves are shown in Fig. 1.5.

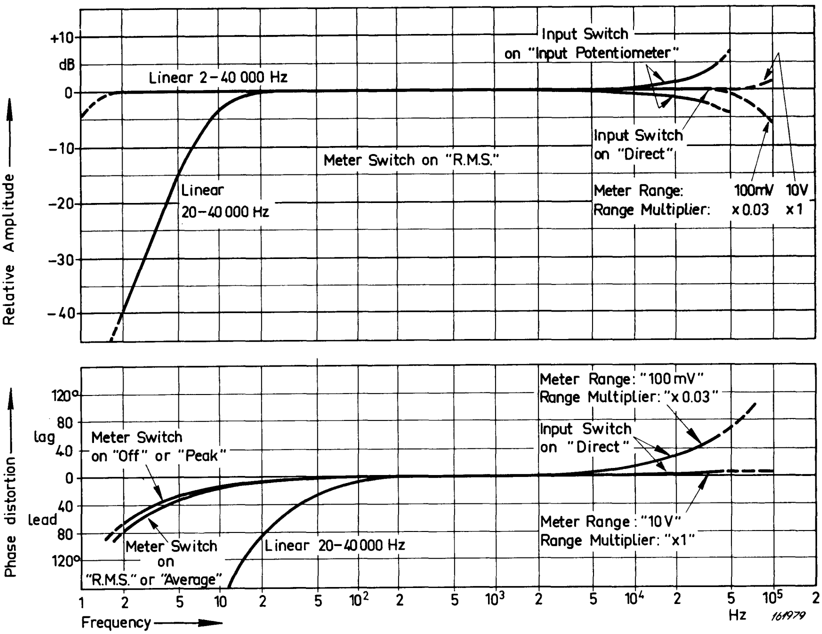


Fig. 1.5. Typical frequency and phase responses of the Microphone Amplifier Type 2603.

The frequency response is plotted for two different cases:—

(a) The input voltage is supplied via either the terminal marked AMPLIFIER INPUT or the one marked CONDENSER MICROPHONE and the INPUT SWITCH respectively placed in the position "Direct" or "Condenser Microphone".

(b) The input voltage is supplied via the terminal marked AMPLIFIER INPUT and the INPUT SWITCH is in position "Input Potentiometer". The influence of the stray capacity in the potentiometer upon the frequency response is clearly noted. Also that this capacity is dependent upon the position of the potentiometer is illustrated. (Two "worst" cases shown).

The two curves shown in the high frequency range of the phase response characteristic indicate the lowest and highest typical phase distortion, obtained for a single apparatus, for all combinations of the METER RANGE and RANGE MULTIPLIER switches.

When analysing or measuring complex signals containing many significant harmonics the upper limit of the frequency range should be noted as the harmonics may be attenuated, thus obtaining an incorrect measurement.

Common amplifiers show a phase distortion which is perceptible a decade or more higher than the lower frequency limit and a decade or more lower than the higher frequency limit. This phase distortion influences especially the peak value and to some extent the average value of complex signals. Therefore, when measuring the peak or average value of complex signals with the Microphone Amplifier its phase response should be taken into account, see also Appendix.

When the Type 2603 is used with the Band-Pass Filter Set Type 1612 the combination becomes similar to an Audio Frequency Spectrometer of the Type 2112, and reference should then be made to the instruction manual for this instrument.

Description of the Power Supply.

The power supply unit of the apparatus contains two rectifiers, one of which supplies the heater current for the instrument and the heater current to the B & K Condenser Microphones or Preamplifiers via the CONDENSER MICROPHONE input socket. The other rectifier supplies the necessary anode voltages for the amplifiers and the polarization voltage for the microphone cartridge of a Condenser Microphone when used. The former voltage is stabilized by means of a zener diode, the latter by two neon tubes. A socket marked POLARIZATION VOLTAGE on the front panel of the apparatus makes is possible to measure the polarization voltage for the microphone cartridges by means of an ordinary sensitive voltmeter (current consumption not more than 50 μA). This voltage can be adjusted around 200 volts by means of a screwdriver-operated potentiometer on the back of the instrument.

Before the instrument leaves the factory, the voltage is set to 200 volts.

Fuse and Mains Voltage Selection.

The equipment should be operated from a 50 to 400 Hz power line and can be set for mains voltages of 100—115—127—150—220 or 240 volts. The power consumption is approximately 50 watts.

The primary side of the power transformer is protected by a fuse placed on the rear of the apparatus. The fuse is incorporated in a combined voltage selector and fuseholder, and to select the appropriate line voltage it is necessary first to remove the fuse and to turn the selector by a coin or similar means until the white mark is lined up with the desired value.

To operate the equipment from an accumulator or other type of DC supply the use of a DC to AC converter is necessary.

2. Identification of Control Knobs, Terminals etc.

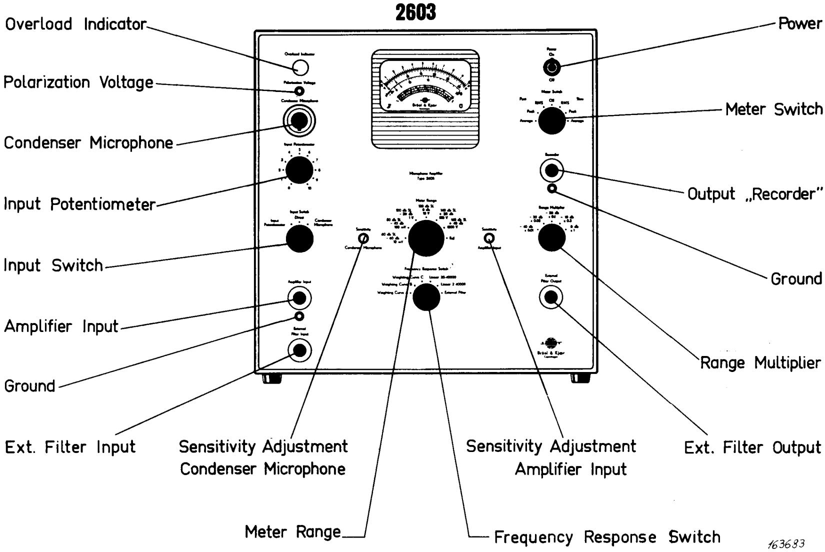


Fig. 2.1. Drawing of Type 2603 with control knob identification.

(Refer Fig. 2.1).

OVERLOAD INDICATOR: Red light indicating that the input amplifier is overdriven (4.5 volts peak at the output of the input amplifier).

POLARIZATION VOLTAGE: For measurement of the microphone polarization voltage. (The measurement should be carried out with a DC voltmeter having an internal resistance of at least 20ooo Ω/volt).

CONDENSER MICROPHONE: Input terminal for the B & K Microphones (and associated Cathode Follower). Also Preamplifier when used.

INPUT POTENTIOMETER: For continuous variation of input signal attenuation.

INPUT SWITCH:

1. "Input Potentiometer", for use in relative measurements at the same frequency.
2. "Direct", the signal is then applied directly from AMPLIFIER INPUT to the attenuator METER RANGE.
3. "Condenser Microphone".

AMPLIFIER INPUT: The signal is applied to the attenuator METER RANGE either directly or via the INPUT POTENTIOMETER.

EXTERNAL FILTER INPUT: For connection of external filter (e.g. the Band-Pass Filter Set Type 1612).

SENSITIVITY, CONDENSER MICROPHONE: A screwdriver-adjusted potentiometer for adjustment of sensitivity when the input CONDENSER MICROPHONE is used.

METER RANGE: A stepped attenuator (20 dB) for attenuation of input signal.

FREQUENCY RESPONSE SWITCH: For the selection of linear amplification in the range 2—40000 Hz, the insertion of the built-in weighting networks A, B or C conforming to IEC recommendations for sound level measurements, or an external filter.

SENSITIVITY AMPLIFIER INPUT: Screwdriver-operated potentiometer for adjustment of sensitivity when terminal AMPLIFIER INPUT is used.

POWER: "On" and "Off" selection of power.

METER SWITCH: Selects three different rectifier and meter indicating properties:—

"Average"
"Peak" (i.e. half peak-to-peak)
"RMS"

Positioned to right or left, high or low damping of the meter can be obtained. In position "Off" the meter is disconnected.

RECORDER: Output terminal for connection to monitoring instruments such as the Level Recorder Type 2305.

RANGE MULTIPLIER: Stepped attenuator (10 dB) for attenuation of the signal level between filter outputs and the output amplifier.

EXTERNAL FILTER OUTPUT: For use when utilizing external filter.

3. Operation

VOLTAGE MEASUREMENTS

Calibration.

1. Bring the Microphone Amplifier in its "Off" position by means of the switch marked POWER on the front panel.
2. Connect the instrument to the power line and make sure that the line voltage selector placed on the rear of the instrument is in its proper position. If not, remove the fuse from the fuseholder and rotate the selector using a coin or similar means until the white mark indicates the desired value for the line voltage.
3. Reinsert the fuse and switch on the power. The scale light should come on immediately, and after a few minutes warm-up time the instrument is ready for use.
4. For calibration of the Microphone Amplifier the control knobs must be set in the following positions:
   INPUT SWITCH: "Direct" or "Input Potentiometer"
   METER RANGE: "Ref."
   FREQUENCY RESPONSE SWITCH: "Linear 2—40000"
   METER SWITCH: "RMS-fast"
   RANGE MULTIPLIER: "× 1 (0 dB)"
   The control knobs not mentioned can be in any position.
5. The meter deflection should now be 16 dB (red mark on the scale). If not, adjust to the correct value by means of the screwdriver operated potentiometer SENSITIVITY-AMPLIFIER INPUT on the front panel.

Measuring.

The Microphone Amplifier has now been calibrated to be used as a linear vacuum tube voltmeter in the frequency range 2—40000 Hz and with an input impedance of 2.2 megohms in parallel with 30 pF.

1. The control knobs must be set in the following positions:
   INPUT SWITCH: "Direct"
   METER RANGE: "1000 V"
   FREQUENCY RESPONSE SWITCH: "Linear 2—40000"
   METER SWITCH: "RMS-fast" or any other of the 2 × 3 possible indicating positions.
   RANGE MULTIPLIER: "× 1"
2. Feed the unknown voltage to the AMPLIFIER INPUT socket and turn the METER RANGE counter-clockwise (20 dB steps) until a suitable deflection is obtained on the meter.

If the deflection is insufficient even though the METER RANGE is in its "10 mV" position further increase in sensitivity will be necessary. This is accomplished by turning the RANGE MULTIPLIER counter-clockwise (10 dB steps). The total reading is then found by multiplying METER RANGE position and RANGE MULTIPLIER position, this value being full scale deflection referring to one of the two upper scales on the meter.

Example 1:

METER RANGE position: "10 V"
RANGE MULTIPLIER position: "× 1"
Full scale deflection is now found as 10 V × 1 = 10 volts, i.e. the 0—10 volts scale has to be used.

Example 2:

METER RANGE position: "10 mV"
RANGE MULTIPLIER position: "× o.3"
Full scale deflection is now found as 10 mV × o.3 = 3 mV, i.e. the 0—31.5 volts scale must be used.

The voltage measured can be recorded on a level recorder such as the Type 2305, which should then be connected to the output socket marked RECORDER. Other monitoring instruments such as oscilloscopes, tape recorders or even high impedance loudspeakers can be used utilizing the RECORDER socket which is able to give 10 volts r.m.s. for full deflection on the meter scale with an output impedance of 50 Ω in series with 24 μF.

SOUND LEVEL MEASUREMENTS

Setting up.

The Microphone Amplifier Type 2603 can operate as a precision sound level meter when used in conjunction with one of the B & K Condenser Microphones 4131, 4132, 4133 or 4134 and a cathode follower of the Type 2612, 2613, 2614

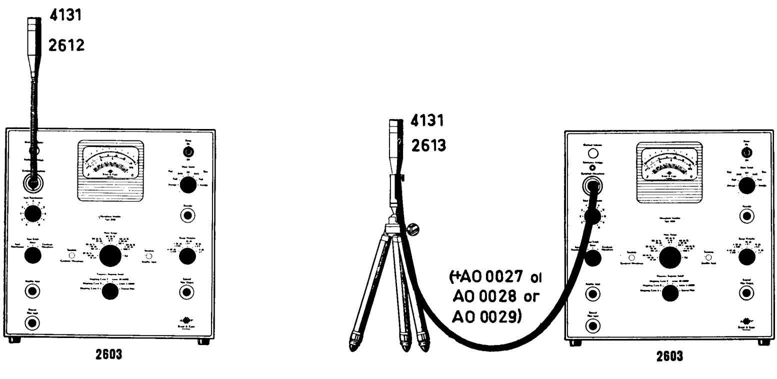


Fig. 3.1. Various methods of connecting the Condenser Microphone to the Amplifier.

or 2615. An extension cable can be used, and it will normally be an advantage to place the Microphone on one of the Microphone Stands UA 0049. Further accessories for the microphones are outlined in their Instruction Books.
The Microphone is connected to the Amplifier by inserting the seven-pin plug into the socket marked CONDENSER MICROPHONE on the front panel, either going directly into the amplifier or using an extension cable (see Fig. 3.1.). Via the seven-pin plug the Microphone is supplied with the voltages necessary for its operation.

Calibration.

1. Insert the seven-pin plug from the Microphone into the CONDENSER MICROPHONE socket (Fig. 3.1).
2. Connect the Microphone Amplifier to the power line and make the same preparations as mentioned under "Voltage Measurements 1-3".
3. For calibration of the Microphone Amplifier + Condenser Microphone proceed as outlined in the following tables.

Microphone 4131 or 4132.

1. Check the microphone polarization voltage.
2. Set the control knobs in the following positions:—
   INPUT SWITCH: "Condenser Microphone"
   METER RANGE: "Ref."
   METER SWITCH: "RMS-fast"
   RANGE MULTIPLIER: "× 1 (0 dB)"
   FREQUENCY RESPONSE SWITCH: "Linear 2—40ooo"
   Control knobs not mentioned can be in any position.
3. Allow 2 minutes to warm up.
4. Next note the correction factor "K" from the calibration chart of the microphone employed (Fig. 3.2).
5. With a screwdriver turn the SENSITIVITY - CONDENSER MICROPHONE potentiometer until the meter pointer deflects to the red mark + the "K" factor in dB. If "K" factor is negative it has to be subtracted from the value which corresponds to the red mark.

Microphone 4133 or 4134.

1. Check the microphone polarization voltage.
2. Set the control knobs in the following positions:—
   INPUT SWITCH: "Condenser Microphone"
   METER RANGE: "Ref."
   METER SWITCH: "RMS-fast"
   RANGE MULTIPLIER: "× 1 (0 dB)"
   FREQUENCY RESPONSE SWITCH: "Linear 2—40ooo"
   Control knobs not mentioned can be in any position.
3. Allow 2 minutes to warm up.
4. Turn the SENSITIVITY - CONDENSER MICROPHONE potentiometer by means of a screwdriver until the meter pointer deflects to the red mark.

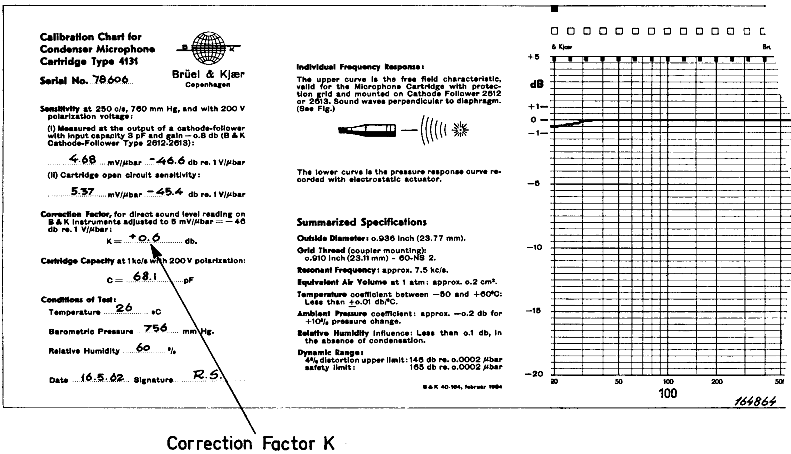


Fig. 3.2. Typical Microphone calibration curve with indication of the factor "K" in dB.

Measuring.

For sound level measurements the control knobs should be in the following positions:

INPUT SWITCH: "Condenser Microphone"

METER RANGE: "160 dB SL"

FREQUENCY RESPONSE SWITCH: "Linear", "Weighting Curves A, B, and C" or "External Filter" as desired.

RANGE MULTIPLIER: "0 dB"

METER SWITCH: "RMS-fast" or other positions as desired.

The control knobs not mentioned can be in any position.

1. The Condenser Microphone should be exposed to the sound field.
2. METER RANGE switch is turned counter-clockwise until a suitable deflection is observed on the instrument meter. If a convenient deflection on the meter cannot be obtained by using METER RANGE switch, the RANGE MULTIPLIER switch may be set to a position with higher sensitivity.
3. The absolute value of the sound level can now be read on the instrument meter using the formulae:

Microphone 4131 or 4132.

The deflection in dB on the indicating meter

\+ the number of dB SL indicated by METER RANGE

\+ the number of dB indicated by RANGE MULTIPLIER

Microphone 4133 or 4134.

The deflection in dB on the indicating meter

\+ the number of dB SL indicated by METER RANGE

\+ the number of dB indicated by RANGE MULTIPLIER

Example 1:—
Deflection of the meter 19 dB
Position of METER RANGE 60 dB SL
Position of RANGE MULTIPLIER —10 dB
Position of FREQUENCY RESPONSE SWITCH "B"
Sound level = 19 dB + 60 dB — 10 dB = 69 dB (B)

Example 2:—
Deflection of the meter 10 dB
Position of METER RANGE 80 dB SL
Position of RANGE MULTIPLIER 0 dB
Position of FREQUENCY RESPONSE SWITCH "B"
Sound level = 10 dB + 80 dB + 0 dB = 90 dB (B)

+ the correction factor "K" in dB ("K" being the correction factor for the microphone).

Example 1:—
Deflection of the meter 15 dB
Position of METER RANGE 100 dB SL
Position of RANGE MULTIPLIER —10 dB
Position of FREQUENCY RESPONSE SWITCH "C"
Correction Factor "K" + 11 dB
Sound level = 15 dB + 100 dB — 10 dB + 11 dB = 116 dB (C)

Example 2:—
Deflection of the meter 19 dB
Position of METER RANGE 60 dB SL
Position of RANGE MULTIPLIER 0 dB
Position of FREQUENCY RESPONSE SWITCH "B"
Correction Factor "K" 16 dB
Sound level = 19 dB + 60 dB + 0 dB + 16 dB = 95 dB (B)

Recording of Sound Level.
In many workshops and offices the noise level will vary considerably with time and if the noise level was determined by means of a single reading it could give way to a serious error being introduced. Therefore, in such circumstances the noise level should be recorded over a relatively long period of time and the record studied, particularly with regard to the value and fre-

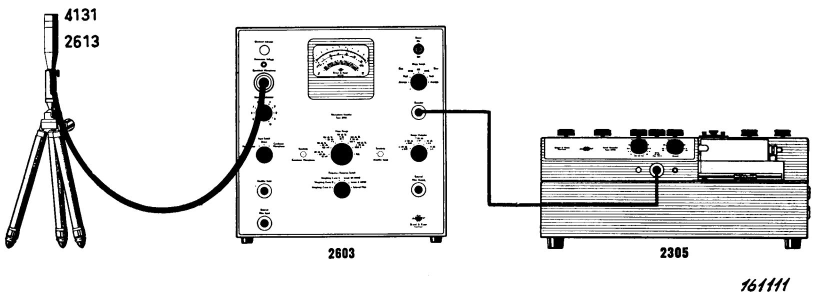


Fig. 3.3. Measuring set-up for recording sound levels in relation to time.

quency of occurrence of noise peaks which are of the greatest interest in relation to health.

A suitable measuring arrangement is shown in Fig. 3.3 and consists of a B & K Condenser Microphone, the Microphone Amplifier Type 2603 and the Level Recorder Type 2305. The following calibration and operating procedure is recommended for this arrangement: Connect the RECORDER output of the Amplifier to the Level Recorder input and supply the Recorder with a 50 dB Range Potentiometer. (Refer Level Recorder Manual if necessary).

1. Measure the sound level referring to the preceding passage "Sound Level Measurements".
2. Next set the control knobs of the Level Recorder Type 2305 as follows:—

POTENTIOMETER RANGE DB:	"50"
RECTIFIER RESPONSE:	"RMS"
LOWER LIMITING FREQUENCY:	"20 Hz"
WRITING SPEED:	"100 (200)"
PAPER DRIVE STOP/START:	"Start"
PAPER DRIVE REVERSE/FORWARD:	"Forward"
POWER:	"On"
MOTOR:	"On"

3. Adjust INPUT POTENTIOMETER in conjunction with INPUT ATTENUATOR until sufficient stylus deflection is obtained, and select a suitable paper drive speed by means of the knob PAPER SPEED.
4. Start the recording by pressing the pushbutton SINGLE CHART — CONT. RECORDING and turning it clockwise to "Continuous Recording".

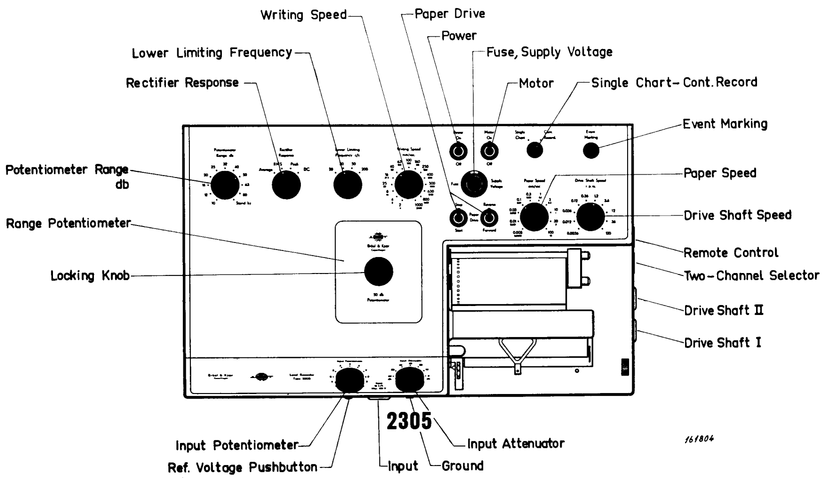


Fig. 3.4. Level Recorder Type 2305 with control knob identification.

5. After the desired period of recording has passed, the Level Recorder motor is stopped, by releasing the pushbutton SINGLE CHART. — CONT. RECORDING, and the paper cut-off. The variations in noise level can then be readily examined.

Remarks: For the necessary calibration of the recording paper use the sound level measured during adjustment. If this varies too quickly to obtain an accurate calibration figure for the measuring set-up it is recommended that use should be made of the *Pistonphone Type 4220* (or the Noise Source Type 4240) prior to commencement.
Calibration by means of the Pistonphone or the Noise Source is carried out as described in the following passages.

Calibration by Means of a Calibrated Sound Source.
An easy way to calibrate or check a measuring arrangement for sound investigation is offered by the employment of the B & K Pistonphone Type 4220 or Noise Source Type 4240 respectively.

I. Pistonphone.
The Pistonphone is compact battery-operated, easily portable device, designed for the calibration of microphones and measuring set-ups. It is very accurate, and the calibration procedure actually consists of measuring the sound pressure level produced by this instrument.

1. The Microphone Amplifier control knobs should be positioned as follows:

Microphone 4131 or 4132.
INPUT SWITCH: "Condenser Microphone"
METER RANGE: "120 dB SL"
RANGE MULTIPLIER: "× o.3 (—10 dB)"
FREQUENCY RESPONSE SWITCH: "Linear 2—40ooo"
METER SWITCH: "RMS-fast"

Microphone 4133 or 4134.
INPUT SWITCH: "Condenser Microphone"
METER RANGE: "100 dB SL"
RANGE MULTIPLIER: "× 1 (0 dB)"
FREQUENCY RESPONSE SWITCH: "Linear 2—40ooo"
METER SWITCH: "RMS-fast"

2. Place the Pistonphone against the Microphone Cartridge and switch on its motor.
3. The indicating meter on the Microphone Amplifier should now deflect to:

Microphone 4131 or 4132.
The value of SPL given in dB on the calibration chart for the Pistonphone less 110 dB.

Microphone 4133 or 4134.
The value of SPL given in dB on the calibration chart for the Pistonphone, less 100 dB and in addition less "K".
"K" is the correction factor in dB valid for the Microphone in use.

Example:

The value of SPL given on the calibration chart 124.2 dB.
The deflection of the indicating meter should then be:
124.2 dB — 110 dB = 14.2 dB.

Example:

The value of SPL given on the calibration chart: 124.2 dB.
The correction factor "K" of the Microphone 13.3 dB.
The deflection of the indicating meter should then be:
124.2 dB — 100 dB — 13.3 dB = 10.9 dB.

4. Possible deviation has to be corrected by means of the SENSITIVITY-CONDENSER MICROPHONE accessible on the front of the Microphone Amplifier.
5. When the Level Recorder Type 2305 is combined with the Microphone Amplifier the deflection of its stylus can readily be calibrated by the Pistonphone. The procedure employed is the same as the one given here.

II. Noise Source.

The Noise Source is designed to give a quick check on measuring arrangements set up for sound investigation. The Source is a cartridge in which steel balls generate the noise level. Further information is given in the manual or data sheet for this device.

1. The procedure for employing the apparatus is similar to that given for the Pistonphone, with the exception that the control knobs of the Microphone Amplifier should now be set as follows:

Microphone 4131 or 4132.

INPUT SWITCH: "Condenser Microphone"
METER RANGE: "100 dB SL"
RANGE MULTIPLIER: "× o.3 (—10 dB)"
FREQUENCY RESPONSE SWITCH: "Linear 2—40ooo"
METER SWITCH: "RMS-fast"

Microphone 4133 or 4134.

INPUT SWITCH: "Condenser Microphone"
METER RANGE: "80 dB SL"
RANGE MULTIPLIER: "× 1 (0 dB)"
FREQUENCY RESPONSE SWITCH: "Linear 2—40ooo"
METER SWITCH: "RMS-fast"

2. The Noise Source is placed against the Microphone Cartridge.
The outer ring of the Noise Source housing should then be turned through 180° whereby the noise is generated by the running of the steel balls.
3. The indicating meter of Microphone Amplifier should now deflect to:

Microphone 4131 or 4132.

The value of SPL written in dB on the Source housing less 90 dB.

Microphone 4133 or 4134.

The value of SPL written in dB on the Source housing less 80 dB and further, less "K".
"K" is the correction factor in dB valid for the Microphone in question.

Example:

Value of SPL given on the housing: 107 dB.

The indicating meter should then deflect to:—
107 — 90 = 17 dB

Example:

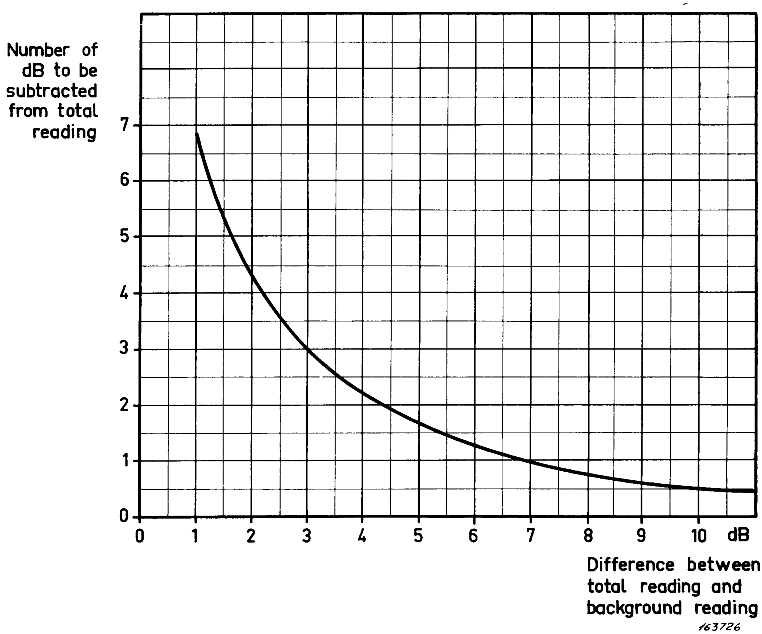
Value of SPL given on the housing: 107 dB.
The correction factor "K" of the Microphone: 13.3 dB.
The indicating meter should then deflect to:—
107 — 80 — 13.3 = 13.7 dB

Influence of Background Noise.

If it is required to measure the sound emitted from a particular piece of equipment, e.g. an electric motor, best results would be obtained by removing the motor and do the measurements in an anechoic room with no disturbing background noise. However, this is not always possible, and the measurements have to be done with the background noise present.

If the background sound level with the motor switched off is much lower than the sound level with the motor running, no correction is required, but if the difference is less than about 10 dB it is necessary to correct for background noise. A graph is given below of the dB value to be subtracted from the total reading for different values of background sound level.

When the difference between total reading and background level is more than 2—3 dB this method is accurate enough for most purposes. However, when smaller differences are measured, the motor noise must be measured in an anechoic room, or the background sound level must be reduced.



4. Accessories

External Filters.

Band Pass Filter Set Type 1612.

As mentioned under "Description" external filters may be inserted between the input and output amplifier sections of the Microphone Amplifier. When the Band Pass Filter Set Type 1612 is used (if convenient combined with the Extension Filter Type 1620) for this purpose it is connected to the FILTER INPUT and FILTER OUTPUT terminals of Type 2603. The INPUT SWITCH of Type 1612 should then be in position "Direct" and the combination (Type 2603 + Type 1612) is now practically equivalent to an Audio Frequency Spectrometer of the Type 2112. For further details concerning the use of the Band Pass Filter Set, the reader is referred to the Instruction Book for the Set. If filters other than the Type 1612 are used in conjunction with the Microphone Amplifier, care should be taken to ensure proper matching. The output impedance of the input amplifier section of Type 2603 is approximately 12 Ω, and in most cases a series resistor must therefore be added to match the filter, see Fig. 4.1. The input impedance of the output amplifier section is 1.46 megohms, and it might therefore be necessary also to parallel the filter output by a suitable resistor.

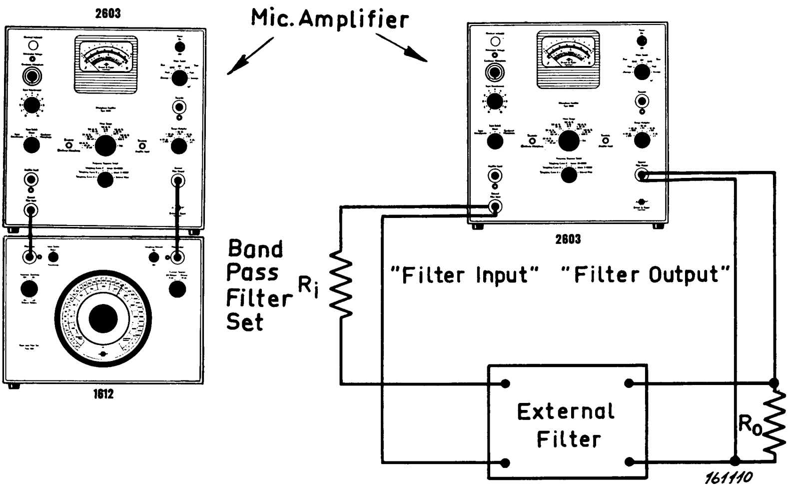
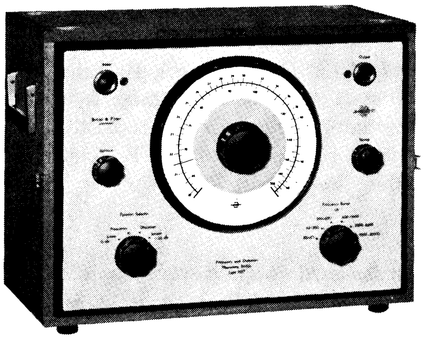


Fig. 4.1. Use of external filters in connection with the Microphone Amplifier Type 2603.

Note: The maximum available (open-circuit) AC voltage from the input amplifier section of Type 2603 is approximately 20 volts, and the DC voltage across the FILTER INPUT terminals is approximately 75 volts (no built-in blocking capacitor).

Frequency and Distortion Measuring Bridge Type 1607.



Frequency and Distortion Measuring Bridge Type 1607.

The Frequency and Distortion Measuring Bridge is an instrument designed for selective attenuation of any frequency within the range 20—20ooo Hz. It consists of a parallel-T network, the resistance components of which are continuously variable within each of six frequency ranges selected by a

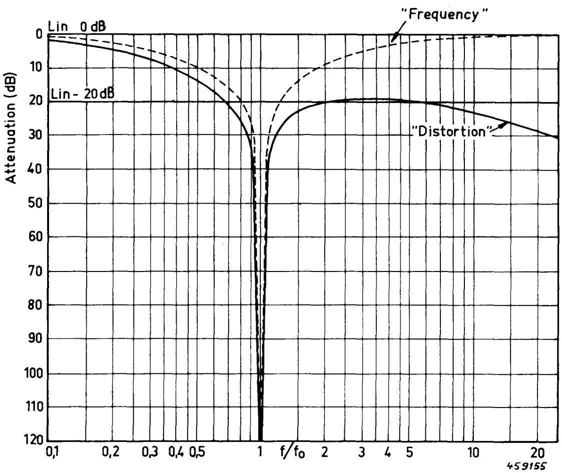


Fig. 4.2. Frequency characteristics of Frequency and Distortion Measuring Bridge. In position "Distortion" the distortion factor is measured. For normal frequency rejection the characteristic "Frequency" is selected.

switch. The selected frequency is easily read from a large scale of 280°. A compensation network which allows the distortion of a signal to be measured in one reading follows the parallel-T network. This compensating network provides a linear frequency response to within ± 1 dB in the frequency range from the 2nd to the 7th harmonic of the signal. See also Fig. 4.2.

When the Bridge is inserted between the Microphone Amplifier sockets FILTER INPUT and FILTER OUTPUT, reading of distortion factors as low as 0.5 % can be obtained in one operation.

In part Application of this book a measuring arrangement is described using the Frequency and Distortion Measuring Bridge for distortion measurements. It should be noticed that the combination consisting of the Bridge and the Microphone Amplifier is equivalent to the Frequency Analyzer Type 2107, when this is in position "Frequency Rejection".

Psophometer Filter ZS 0301.

This Filter has been designed for noise measurements in radio broadcasting audio systems. It is a special frequency weighting filter as required by C.C.I.F. (C.C.I.R., C.C.I.T.T.). The input impedance is somewhat frequency dependent (2000—600 Ω).

Psophometer Filter ZS 0301.

The FILTER INPUT should be connected to a low source impedance (10 Ω or lower) and a maximum voltage of 3 volts approx. (Max. Crest-factor 5). The FILTER OUTPUT should be loaded by 146 kohms. When the filter is used in connection with the Microphone Amplifier Type 2603 (as "External Filter") the filter input condition is fulfilled. A load resistance of 162 kohms should be connected in parallel with the filter output to obtain matching. Notice that, using cables other than the B & K AO 0013 or AO 0014 for connecting the filter, the cable capacity should be lower than 250 pF in order to keep the filter characteristics within the tolerances permitted in the standards.

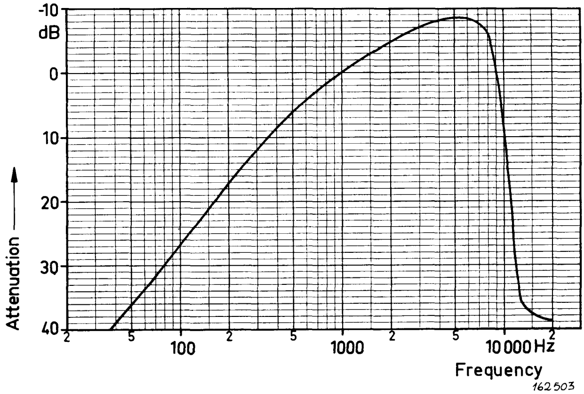


Fig. 4.3. Typical frequency characteristic of ZS 0301.

Condenser Microphones.

When employing one of the B & K Condenser Microphones in conjunction with a Microphone Amplifier Type 2603 a complete equipment for high precision measuring and analyzing of sound is produced. The B & K Condenser Microphone program is very extensive and is constantly progressing. The predominant part of the program is centered around the Microphone Cartridge and the associated Cathode Follower (which constitute the Condenser Micro-

Condenser Microphones.

phone), but includes a wide range of accoutrement which makes it possible to cover the majority of sound investigations. Due to the extensive program only some data for the Microphone Cartridges and their associated Cathode Followers are listed here:—

SPECIFICATION

Microphone Cartridge Type	**4131**	**4132**	**4133**	**4134**	**4135**	**4136**
Frequency Response. Flat.*) Free-field Pressure Random incidence and pressure	20 Hz to 18 kHz	20 Hz to 7 kHz	20 Hz to 40 kHz	20 Hz to 20 kHz	30 Hz to 100 kHz	30 Hz to 80 kHz
Sensitivity Approx.*)	5 mV/μbar (—46 dB re 1 V/μbar		1 mV/μbar (—60 dB re 1 V/μbar)		o.2 mV/μbar (—74 dB re 1 V/μbar)	o.1 mV/μbar (—80 dB re 1 V/μbar)
Dynamic Range, re 2×10^{-4} μbar "A"-weighted to 4 % distortion	15—146 dB		32—160 dB		64—174 dB	70—180 dB
Maximum Safe Sound Pressure, re 2×10^{-4} μbar	165 dB		180 dB		185 dB	
Temperature Coefficient	Less than ± o.01 dB per °C					
Construction. Cylindrical. Outside diameter	23.77 mm (o.936")		13.2 mm (o.52")		7.4 mm (o.29")	
Ambient Pressure Coefficient. 100 mm Hg pressure decrease equals a sensitivity increase of	o.2 dB		o.1 dB		Less than o.1 dB	
To be employed with Cathode Follower Type	2612 or 2613		2614 or 2615		2614 or 2615 + Adaptor UA 0035	

*) Individually calibrated.

<table>
<tr><th>Cathode Follower Type</th><th>2612—2613</th><th colspan="2">2614—2615</th></tr>
<tr><td>Input Impedance</td><td>Approximately 270 MΩ paralleled by 3 pF.</td><td colspan="2">Approximately 700 MΩ paralleled by 2.5 pF.</td></tr>
<tr><td>Self-Generated Noise Level</td><td>Less than 30 μV for the frequency band 20—20000 Hz (input loaded by 60 pF).</td><td colspan="2">Less than 40 μV for the frequency band 20—200000 Hz (input loaded by 20 pF).</td></tr>
<tr><td>Sensitivity to Vibration</td><td>(Cathode Follower with Microphone Cartridges 4131/4132). Less than 85 dB re 0.0002 dyn/cm² for 1 G excitation in any direction.</td><td colspan="2">(Cathode Follower with Microphone Cartridges 4133/4134). Equivalent to 88 dB re 0.0002 dyn/cm² for 1 G excitation.</td></tr>
<tr><td>Sensitivity to Sound Fields</td><td colspan="3">Loaded with dummy cartridges and placed in a 130 dB Sound Field the Cathode Follower output is 50 dB below normal microphone output.</td></tr>
<tr><td>Working Temperature</td><td>2612—2613
From below — 40° C to above 100° C.</td><td>2614
From below — 40° C to above 150° C (above 250° C intermittent).</td><td>2615
From below — 40° C to above 100° C.</td></tr>
</table>

To give an impression of the area of application, some of the most important accessories are mentioned:—
Artificial Ear Type 4152, Artificial Voice Type 4216, Pistonphone Type 4220, Microphone Calibration Apparatus Type 4142, Noise Source Type 4240, Nose Cones (various types), Wind Screen UA 0050, Probe Microphone Kit UA 0040, Floor Stand UA 0049, Electrostatic Actuators (various types), Extension Cables (various lengths) etc.

The Two-Channel Microphone Selector Type 4408.
This piece of equipment (Fig. 4.4) is designed as an accessory to the Analyzers and Microphone Amplifiers produced by Brüel & Kjær and allows the output from two alternate B & K Condenser Microphones to be separately switched, automatically or manually, into a single amplifier. A recording of two phenomena, e.g. the sound pressure at two different points in a sound field, can thus be obtained on a Level Recorder.
The Microphone Selector is built in a metal box and contains a toggle switch which operates a relay,—and the necessary components for the elimination of hum and cross-talk effects. Cross-talk is negligible, but it is greatest at the lower frequencies due to coupling in the HT supply between the two anodes. Still it is reduced by more than 80 dB at 20 Hz.

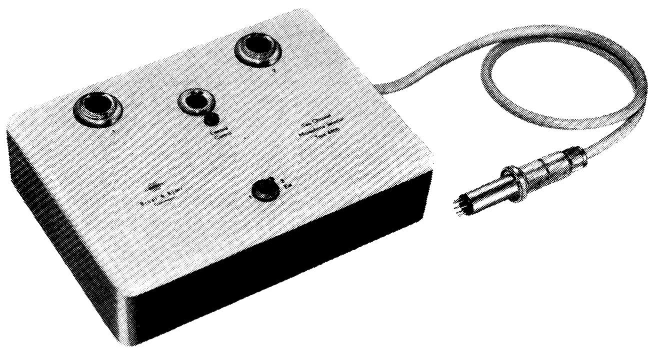


Fig. 4.4. The Two-channel Microphone Selector Type 4408.

When the Selector is operated manually the toggle switch is employed. This switch then operates the relay, which in turn switches the output from the Type 4408 to one or the other of the two inputs. The Selector may also be remotely controlled. The toggle switch must then be in position "2", and the external control switch is connected by means of a cable to the terminals marked EXTERNAL CONTROL, the external switch then replacing the function of the toggle switch.
(Note should be made that due to series heating of the tubes the Type 4408 can only be used when both microphones are connected).

Response Test Unit Type 4409.
The Response Test Unit Type 4409 is intended for use with the B & K automatic frequency response plotting equipment when investigating the frequency response of sound reproducing equipment.
The 4409 fulfils three different functions:
(a) channel selection in the case of stereophonic equipment either manually,

Response Test Unit Type 4409.

when only one channel is investigated, or automatically at a recurring frequency of 1.2 Hz for automatic cross-talk or comparison measurements.

(b) equalization, by different RC filters, of the recording characteristic of the test record.

(c) synchronization of the paper-drive of the Level Recorder Type 2305 with the reference recordings (record or tape) under reproduction.
It is thus possible to automatically plot the frequency response of the sound reproducing equipment.

Where the recorder is integrated with the reproducer, as in the case of tape recorders, motion picture systems etc., reference recordings are taken from the constant voltage output of a generator, but in the case of phonograph testing, accurate reference disc recordings are needed.
The Gliding Frequency Recordings Type QR 2007 and 2009 are especially designed for the purpose of frequency response investigation. They provide continuous frequency sweeps from 20 Hz to 20 kHz with lateral modulation on the QR 2007 and left, right, lateral, vertical modulations on the QR 2009.
The Pickup Test Record QR 2008 is, on the other hand, designed for measurements at fixed frequencies and for tone arm resonance investigations. It is intended for pick-up design work, and also for general purpose checks in combination with the gliding frequency records when curve plotting equipment is not available.
The Response Test Unit Type 4409 consists of three sections, the channel selector, the equalizing filter section and the synchro-starter. The channel selector is a low-noise relay driven by a multivibrator and it is possible either to select individually the left and right channel signals from the record player or to alternate between the two signals at a recurring frequency of 1.2 Hz, the switching time being negligible. The equalizing filters are RC networks designed as external filters for the amplifier used, e.g. the Microphone Amplifier Type 2603 (see part Application in this book). The filter characteristics are in accordance with International Standards dealing with stereophonic and monophonic recordings.
The synchro-starter commands the paper drive start of the Level Recorder de-energizing the spring loaded electromagnetic clutch for the paper drive when a 1 kHz start-signal from the test record is fed into the selective amplifier of the synchro-starter. The remote control cable between the Type 4409 and the Level Recorder for control of the paper drive also includes the 24 volts power supply for the Response Test Unit.
For further details concerning the Type 4409 the reader is referred to the Instruction Book for this apparatus.

Artificial Ear Type 4152.

The Artificial Ear Type 4152 (Fig. 4.5) is designed to enable acoustical measurements on earphones or hearing aids to be carried out under well-defined acoustical conditions.

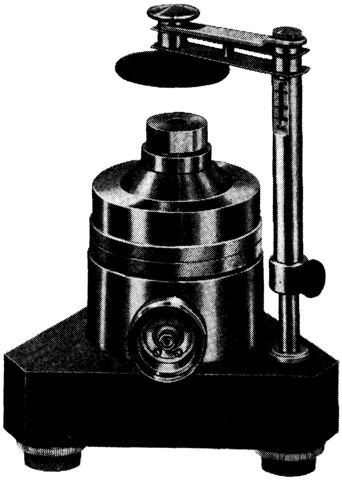


Fig. 4.5. Artificial Ear Type 4152.

It consists basically of a replaceable acoustic coupler and two sockets for the mounting of a Condenser Microphone Cartridge Type 4132 and the Cathode Follower Type 2613.
A spring arrangement is provided to fulfil certain standards requirements regarding the force applied to the object under measurement.
Three acoustic couplers are available for the Artificial Ear, all constructed in such a way that they are in accordance with International Standards.

Hearing Aid Test Box Type 4212.

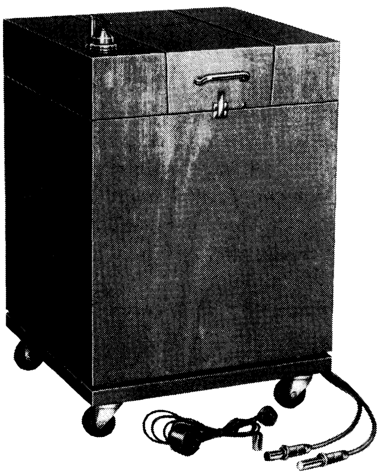


Fig. 4.6. Hearing Aid Test Box Type 4212.

In measuring the free-field response and distortion of complete hearing aids and small microphones the Hearing Aid Test Box is an indispensable equipment.
The Test Box is portable and consists of a small anechoic chamber with a built-in loudspeaker and regulating microphone as well as an artificial ear, which contains a 2 cm^3 coupler, specially designed for use both on hearing aids with built-in earphones and the conventional types. The artificial ear, when included with the 2 cm^3 coupler, is in accordance with the ASA standard Z 24. 9 as well as the international IEC standard. The regulating microphone is included within a compressor (servo) circuit allowing a constant sound pressure level to be maintained at the hearing aid microphone. The regulating microphone is so situated that it does not influence the practically free sound field conditions that exist in the Test Box. By placing the hearing aid earphone in the artificial ear it is possible to measure the overall characteristics of the device with relation to acoustical input and output.
In part Application of this book a measuring arrangement is described using the Hearing Aid Test Box as an integrative part.

Vibration Pick-Up Preamplifier Type 1606.

When the Microphone Amplifier is utilized in vibration measurements a preamplifier for the B & K Accelerometers is a necessity. Therefore, the Vibration Pick-up Preamplifier has been designed. It is connected to the CONDENSER MICROPHONE input, from where the necessary power to the Preamplifier is also supplied.
A measuring arrangement built up of one of the B & K Accelerometers, the Preamplifier and the Microphone Amplifier allows all three values of vibration (i.e. displacement, velocity and acceleration) to be measured in the frequency range 2 Hz—40 kHz.
The Preamplifier contains, along with the amplifier stages, integration networks which make it possible to convert the acceleration signal from the Accelerometer into a velocity or displacement dependent signal. For calibration

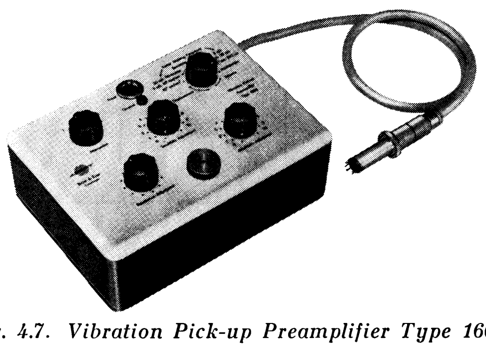


Fig. 4.7. Vibration Pick-up Preamplifier Type 1606.

of the complete measuring arrangement the Preamplifier is furnished with a built-in exciter calibrating at 1 G*).
A measuring arrangement together with an example of a measurement where the Preamplifier is employed in conjunction with the Microphone Amplifier, can be found in part Application of this book.

Input Transformer TI 0001.

By connecting this Transformer to the AMPLIFIER INPUT of the Microphone Amplifier a symmetrical input with respect to ground can be obtained. The Transformer has two input impedances which are selected by a switch INPUT IMP. The impedances are 20 kohm and 600 Ω. A third position of the switch allows a grounded middle point of the INPUT to be utilized. Vide Fig. 4.9.

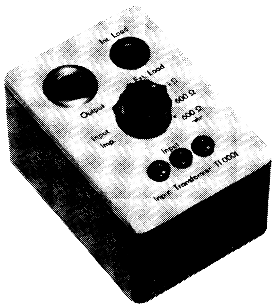


Fig. 4.8. Input Transformer TI 0001.

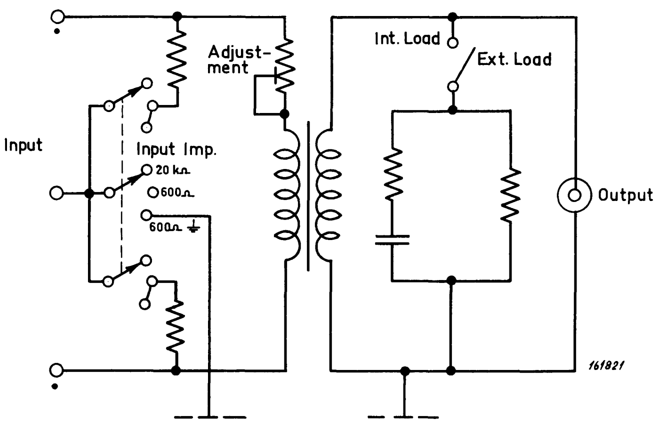


Fig. 4.9. Schematic diagram of Input Transformer.

*) 1 G = acceleration of gravity.

To give a flat frequency response, 10—20ooo Hz $\pm$ o.2 dB, the OUTPUT of the Transformer should be properly loaded. First, to ensure that a low capacity is connected to the OUTPUT of the Transformer the special low-capacity cable AO 0018 delivered with the Transformer should always be used when connected to the Microphone Amplifier. Secondly, to ensure the proper resistive load, the toggle switch on the Transformer should be set in position "Int. Load". Great efforts are made to make the Transformer insensitive to externally inductive stray fields, therefore it has been furnished with a double mumetal screen. Due to this the sensitivity to a field of 50 Hz and 50 gauss corresponds to less than 1 mV on the OUTPUT terminal when the Transformer has an open INPUT terminal and is located in the most unfavourable position in the field.

The transformer ratio 1 : 1 can, if necessary, be adjusted by a potentiometer "Adjustment" accessible at the bottom. The Transformer is correctly pre-adjusted at the factory.

5. Combined Units

Most B & K instruments can be delivered in three different versions, and the user can therefore, to his individual choice, order just that configuration, which is convenient to his use.
The mechanical design is such that the instruments, which are delivered in lightweight metal cases (Type A) as a standard fitting, can very easily be mounted in any of three ways, i.e.:
Mahogany cabinet (Type B), frame for 19″ standard rack (Type C), or B & K combination mounting unit.

Automatic Frequency Response Recorder Type 3329.
This is a Unit containing three instruments, the Beat Frequency Oscillator Type 1022, the Microphone Amplifier Type 2603 and the Level Recorder. The

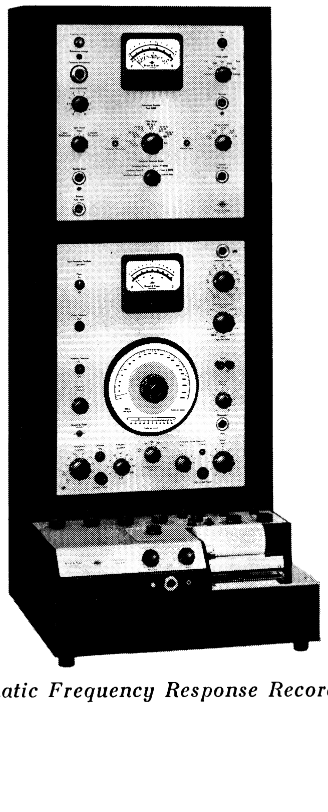


Fig. 5.1. Automatic Frequency Response Recorder Type 3329.

combination is very versatile as the included Microphone Amplifier can be used to amplify weak signals before being applied to the Recorder. Furthermore the Amplifier can be used as a compressor amplifier (in a servo loop) for the Beat Frequency Oscillator. A great variety of amplitude/frequency response curves can be automatically recorded by the unit. The recording papers employed are the preprinted amplitude/frequency calibrated Types QP 0123, QP 0423 and QP 1123.
The Oscillator and the Level Recorder are mechanically connected by means of a built-in permanent chain drive. Consequently no external mechanical shaft between Recorder and Oscillator is necessary.
For a detailed description of the separate instruments and the operation procedure of the Unit the reader is referred to the respective paragraphs in the respective Instruction Books.

Automatic Frequency Response Recorder Type 3334.
This combination consists of three instruments, the Sine-Random Generator Type 1024, the Microphone Amplifier Type 2603 and the Level Recorder Type 2305, all housed in metal cabinets (A-version) and put together in the B & K rack mounting system.
The combination is similar to the Type 3329 mentioned above, except for the Generator, which in this case is the Sine-Random Generator Type 1024. This enables a great variety of measurements to be carried out where the presence of random noise is a necessary condition, e.g. acoustical tests such as required by International Standards for measurements on sound insulation, reverberation time, etc. A few examples of measuring set-ups involving the combination Type 3334 can be found in part Application in this book.
The Generator and the Level Recorder are mechanically connected as described under the Automatic Frequency Response Recorder Type 3329.
For the description and operation procedure the reader is referred to the respective paragraphs in the Instruction Books for the various instruments.

6. Applications

In order to give a general view of the possible applications of the Microphone Amplifier Type 2603 as a separate measuring instrument or when combined with other equipment, some of the more common measuring arrangements are outlined in the following. For acoustical applications the Microphone Amplifier should be equipped with one of the B & K Condenser Microphones suitable for the measurements in question. For information concerning these and other instruments used in the described applications reference should be made to part Accessories in this book or to the respective leaflets and manuals.

A. ELECTRICAL MEASUREMENTS

Distortion Measurements.

The non-linear distortion in four-terminal networks is normally expressed by means of the formula:

$$d = 100 \sqrt{\frac{A_2^2 + A_3^2 + A_4^2 + \dots}{A_1^2 + A_2^2 + A_3^2 + \dots}} \simeq 100 \frac{\sqrt{A_2^2 + A_3^2 + A_4^2 + \dots}}{A_1} \%$$

The factor "d" can be measured directly in one single measurement when the Microphone Amplifier Type 2603 is used in connection with the Frequency and Distortion Measuring Bridge Type 1607 and the Beat Frequency Oscillator Type 1022 (Fig. 6.1)

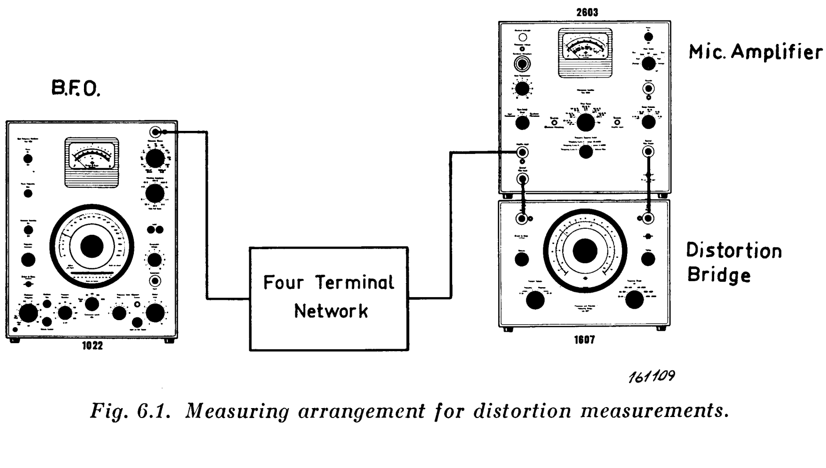


Fig. 6.1. Measuring arrangement for distortion measurements.

To determine the distortion factor "d" the complete signal must be fed into the Microphone Amplifier which should be adjusted for full scale deflection on the meter using the INPUT POTENTIOMETER with the INPUT SWITCH in "Input Potentiometer" position. The FUNCTION SELECTOR of the Distortion Bridge should be in its "Linear - 20 dB" position. By blocking out the fundamental frequency by means of the Frequency and Distortion Measuring Bridge the distortion factor can now be read directly in % from the Microphone Amplifier meter provided that the meter circuit is switched to measure the r.m.s. value of the signal. The B.F.O. itself has a distortion factor of 0.1 % in the middle frequency range when unloaded. It therefore allows measurement of distortion factors down to around 0.5 %, which is sufficient in most practical cases.

Microphone Amplifier 2603 as Bridge Indicator.

When making bridge measurements in the audio frequency range a reliable and sensitive indicating instrument should be used in the bridge network. The Type 2603 adequately satisfies these requirements.

The bridge must have one diagonal point grounded as shown in Fig. 6.2. It is thus supplied from an oscillator via a screened transformer such as the Output Transformer TU 0005, the signal generator also being grounded at one terminal. Should the quality of the different components placed within the bridge have to be measured, the decibel scale on the instrument meter will prove extremely useful.

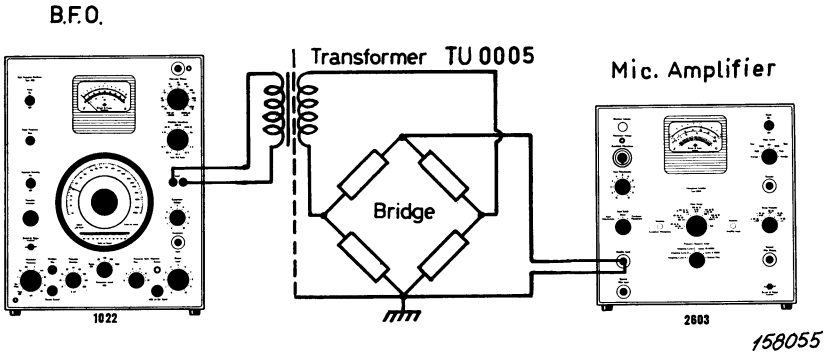


Fig. 6.2. Amplifier Type 2603 used as a bridge indicator.

Automatic Recording of Electrical Impedance.

By using the Automatic Frequency Response Recorder Type 3308 it is possible to record automatically the numerical value of the impedance or the admittance of a two-terminal network as a function of frequency. The impedance is measured by keeping the current through the test object constant, and recording the voltage across the object, while the admittance can be found by keeping the voltage constant and measuring the current.

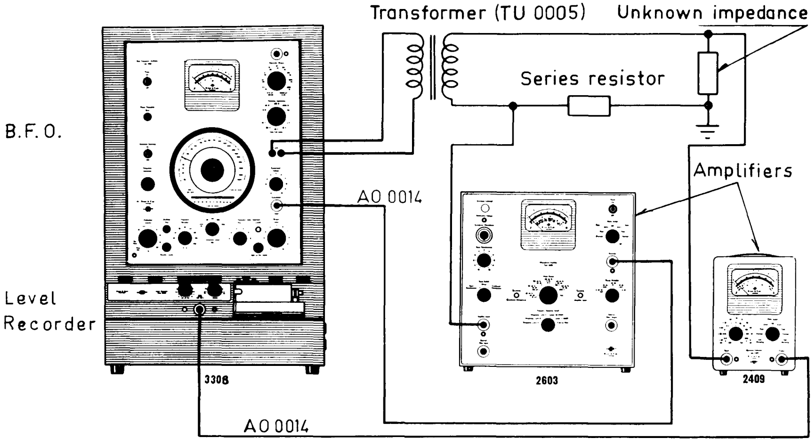


Fig. 6.3. Measuring set-up for automatic recording of the electrical impedance of a two-terminal network.

Fig. 6.3 shows a measuring arrangement suitable for this type of measurement. The current is kept constant by supplying the COMPRESSOR INPUT with the voltage drop across a series resistor.
To be able to separate the ground connections it is necessary to use a screened balancing transformer between the B.F.O. and the object to be measured. Measurement of the admittance can be done in a similar set-up. In this case the connection to the Level Recorder and the COMPRESSOR INPUT have to be interchanged. This method is very convenient for a quick and easy check of the frequency dependance of an unknown impedance.

B. ACOUSTICAL MEASUREMENTS

Checking of Hearing Aids.

An arrangement for the checking of Hearing Aids is illustrated in Fig. 6.4. 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, 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 or lower depending on the background noise level.
The hearing aid and the regulating microphone are placed symmetrically in the sound field. The regulating microphone is connected to the Microphone

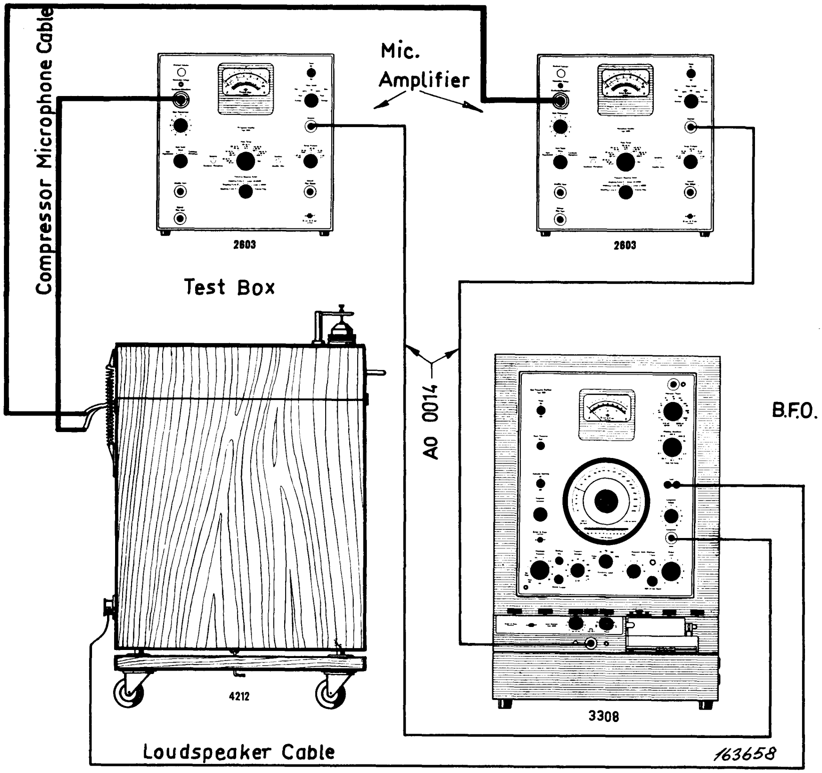


Fig. 6.4. Arrangement for automatically checking the frequency characteristic of a hearing aid.

Amplifier Type 2603, which amplifies the signal and then applies it to the COMPRESSOR INPUT of the B.F.O. Type 1022. This combination enables the sound pressure level on the hearing aid to be kept constant without influencing the practically free sound field conditions.

The B.F.O. Type 1022 supplies the required power for 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 acoustical output from the hearing aid. The microphone is connected to a Microphone Amplifier Type 2603, and the amplified voltage is led to the input of a Level Recorder Type 2305.

Fig. 6.5 shows typical characteristics of a hearing aid device automatically recorded with the arrangement described in Fig. 6.4. (N.B. Recordings are taken for two different settings of the hearing aid volume control).

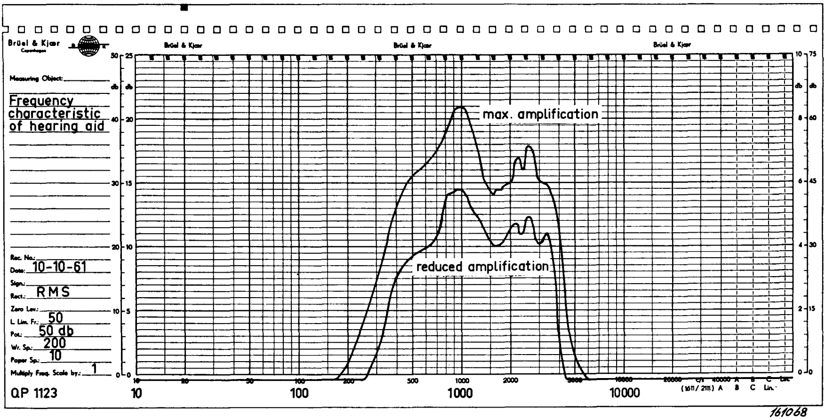


Fig. 6.5. Recording by Fig. 6.4. Taken for different settings of the hearing aid volume control.

It should be noticed that by connecting a Band Pass Filter Set Type 1612 to the Microphone Amplifier which is connected to the Level Recorder, using the Type 1612 as "External Filter", makes it possible also to record automatically the harmonics of the hearing aid. This is accomplished by connecting the Remote Control Cable AQ 0002 between the Level Recorder (7 pin socket) and the Type 1612 and setting the filter switch of the Band Pass Filter Set so that it runs ahead of the frequency scanning of the B.F.O., the selected frequency difference being in accordance with the harmonic which is going to be measured.

Automatic Recording of Airborne Sound Insulation.

Fig. 6.6 illustrates a set-up which will measure the sound insulation property of a wall with respect to airborne sound. The wall separates two rooms one of which is used as "transmitter room" and the other as "receiver room".

In the arrangement only one Microphone Amplifier Type 2603 is required, as the Two-Channel Microphone Selector Type 4408 is utilized. This Selector is connected to the Two-Channel Selector Socket in the Level Recorder section of the Automatic Frequency Response Recorder Type 3309 allowing each Microphone to be selected automatically. By this system the sound levels in the "transmitter" and "receiver" rooms are recorded alternately, as the Generator of the Automatic Frequency Response Recorder traverses the frequency range 20—20ooo Hz.

The Sine-Random Generator Type 1024 gives a narrow band noise signal with constant spectrum density and with a continuously variable center frequency. By feeding this signal to the loudspeaker(s) it is possible to produce a fairly diffuse sound field in the reverberant rooms.

By the following formula the sound insulation value can now be calculated:

$$D_{eff} = L_1 - L_2 + X$$

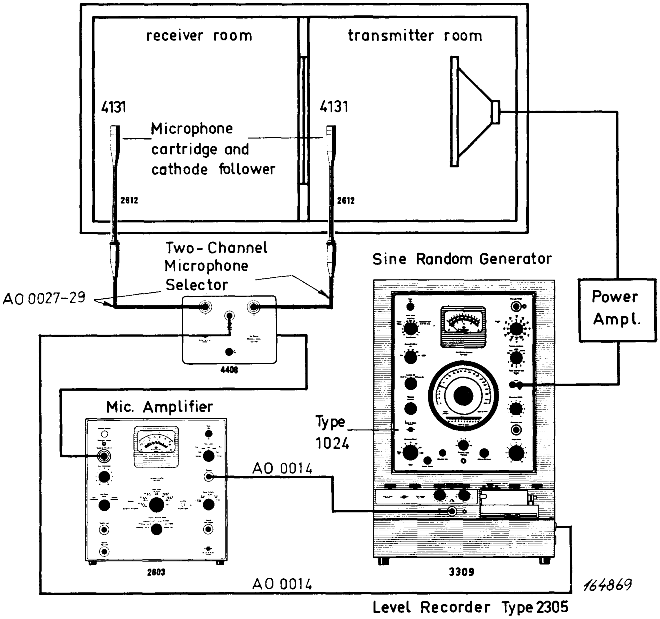


Fig. 6.6. Measuring arrangement for automatic recording of the sound insulation properties of a wall.

where L_1—L_2 is the sound level difference between the rooms, obtained from the recording and X is the correction factor which takes the sound absorption of the receiver room into account.

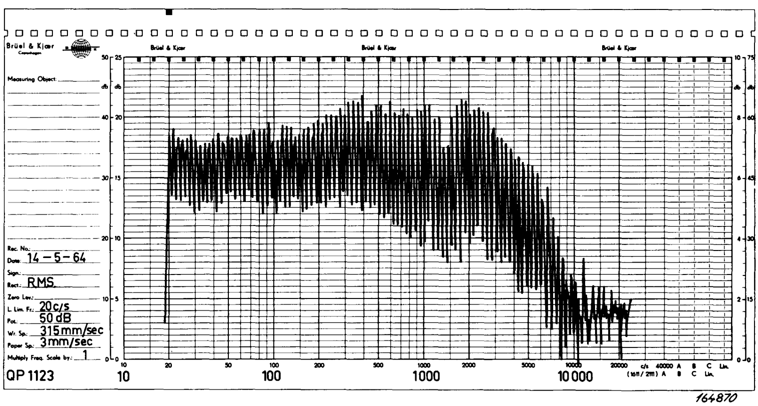


Fig. 6.7. Recording of measurements carried out with an arrangement as shown in Fig. 6.6. A 50 dB potentiometer is used on the Level Recorder.

A narrow band noise signal can also be obtained by using the Noise Generator Type 1402 in conjunction with a Filter Set Type 1612. Both of the above mentioned methods of measurement may require selective signal reception to reduce the influence of background noise. This can be done by supplying the Microphone Amplifier with a Band Pass Filter Set Type 1612 used as "External Filter" and connected to the Level Recorder Type 2305 by means of the Remote Control Cable AQ 0002 as described earlier.

Measurement of Reverberation Time.

One of the most important factors in determining the acoustic quality of a room is the measurement of the room's reverberation time. The Sine-Random Generator includes special functions, such as the compressor circuit and the possibility of generating narrow band noise signals which makes it very suitable for this type of measurement. The compressor circuit can, if used correctly, keep the sound radiated in the room at a constant value throughout the frequency range normally used for the measurements. The noise signal radiated in the room ensures that a great number of eigentones of the room are excited in the frequency band covered by the noise signal. The recorded reverberation decay curves will then appear as smooth curves. This will not be the case when a pure sine-wave signal is radiated in the room, as distinct standing waves will arise. Various measuring arrangements can be set up. The one illustrated in Fig. 6.8 is designed to make automatic measurements of reverberation time and it consists basically of the Sine-Random Generator Type 1024, a loudspeaker with power amplifier, a B & K Condenser Microphone, a Microphone Amplifier Type 2603 and a Level Recorder Type 2305, the Recorder being mechanically coupled to the Sine-Random Generator.

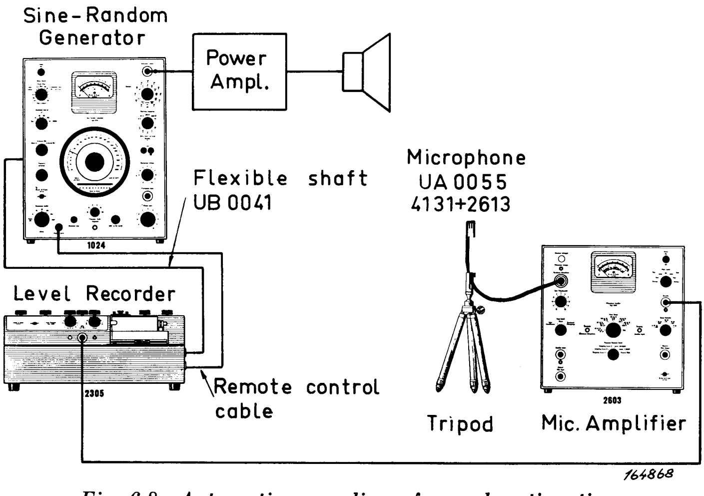


Fig. 6.8. Automatic recording of reverberation time.

For recording the decay of the sound in a room the source has to be disconnected at certain intervals. This is achieved by stopping the Generator. To ensure that only that part of the measurement which is of interest is recorded, the writing pen should lift from the paper in the interval between two decays, and if selective reception is used (Band Pass Filter Set Type 1612 as "External Filter" for the Microphone Amplifier) the filters should be switched successively. The disconnecting of the sound source, the lifting of the pen and the switching of the filters can all be controlled by a special switch in the Level Recorder (The Two-Channel Selector). The necessary connections between the various instruments are shown in Fig. 6.9. The mechanical drive for the Generator should be connected to Drive Shaft II of the Level Recorder.

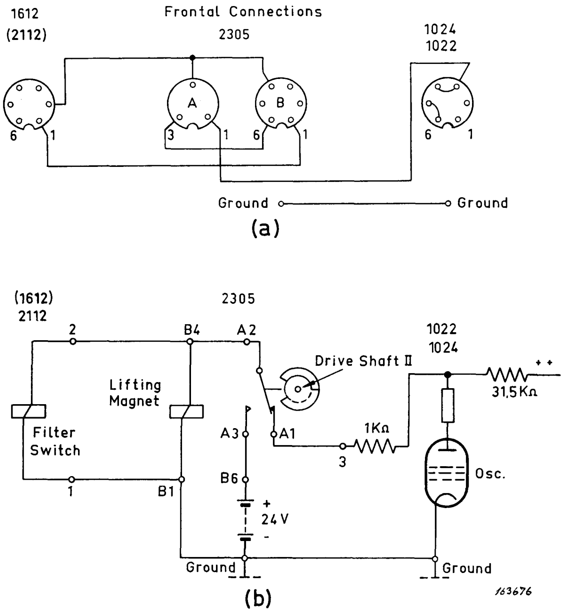


Fig. 6.9. Connection between instruments. a) The remote control sockets. b) Electrical circuit.

When placing a loop of 50 mm paper width (Fig. 6.10) 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 as shown in Fig. 6.11. By cohesively synchronizing the paper movement with the frequency scanning of the Generator as well as the filter switching of the Band Pass Filter Set (if used) and the switching off moment of the sound, the starting points of the decay curves will correspond to the center frequency of the

Overlapping junction.

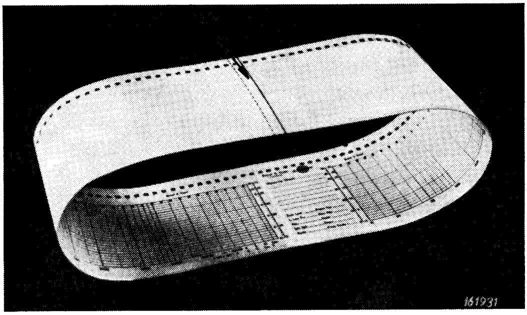


Fig. 6.10. Construction of paper loop. The dotted line illustrates the necessary overlap at the junction.

respective filters. These are represented by small squares on top of the pre-printing on the recording paper, see Fig. 6.11.
It is possible, to a certain degree, to keep the sound pressure level at the point of measurement independent of loudspeaker and room responses 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.

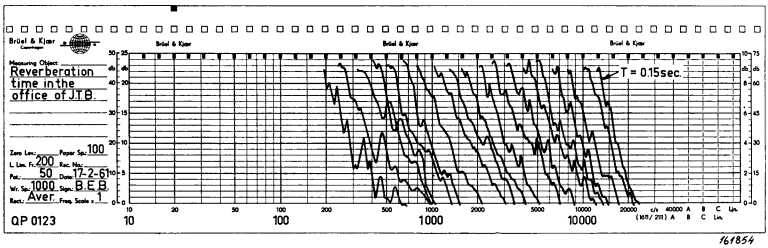


Fig. 6.11. Reverberation decay curves with a spacing of 1/3 octave (5 mm). Compressor arrangement used.

Non-Frequency Calibrated Paper. When a larger spacing than 5 mm between the decay curves is desired (vide example in Fig. 6.12), 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 has to be carried out on the lined recording paper, e.g. QP 0102, QP 1102 or QP 0402 and it is necessary to "mark" one or more frequencies on the paper. The marking can be readily done by means of the Level Recorder's EVENT-MARKER arrangement.
Additional Brüel & Kjær literature: Technical Review, No. 3-1956.

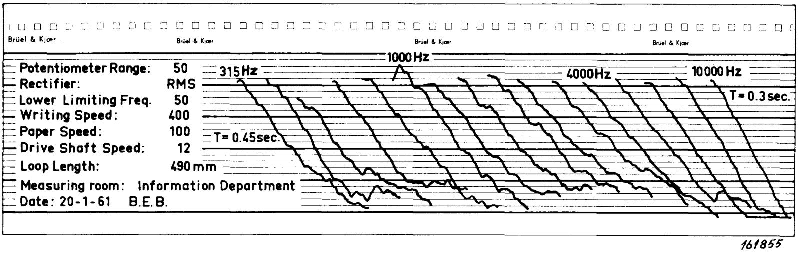


Fig. 6.12. Reverberation decay curves with a spacing of 10 mm. Compressor arrangement used.

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 width paper. 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 recording paper. Refer Fig. 6.13.
2. The reverberation time in seconds is then read on the scale at the point through which the horizontal line passes. Vide Fig. 6.13.

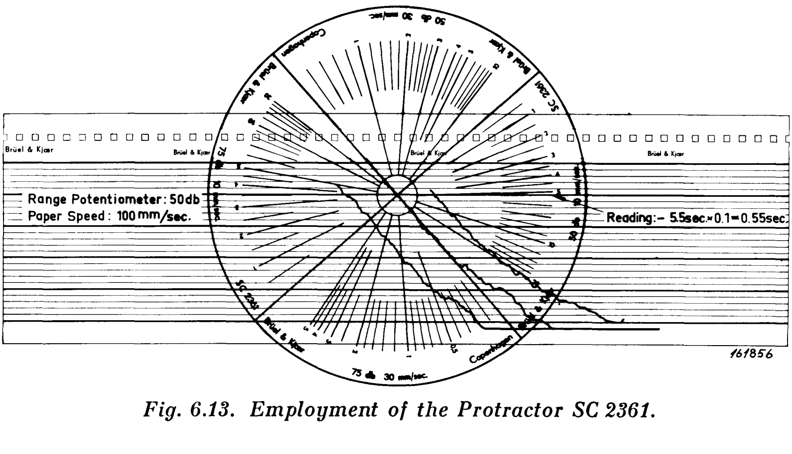


Fig. 6.13. Employment of the Protractor SC 2361.

The decay curves should preferably be approximated into straight lines 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. 6.13.

If the decay curves are recorded on 100 mm paper width, the results measured by the protractor have to be multiplied by 2.

Measurement of Acoustic Absorption Coefficients.

Small samples can be tested for their acoustical absorption by means of the Standing Wave Apparatus Type 4002 as shown in Fig. 6.14.

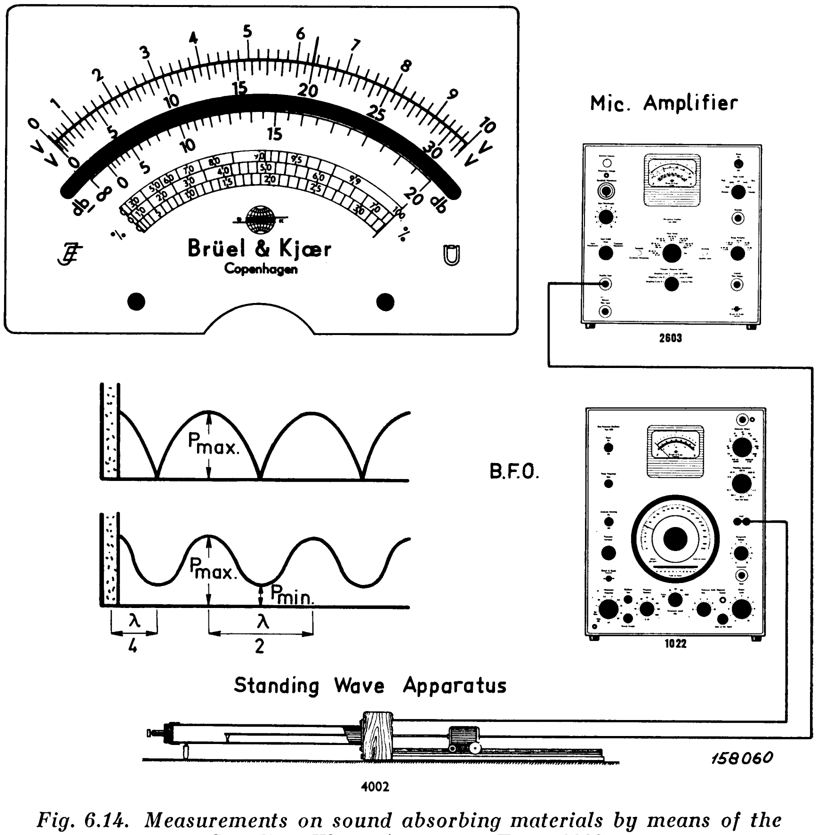


Fig. 6.14. Measurements on sound absorbing materials by means of the Standing Wave Apparatus Type 4002.

The layout demonstrates the method of connecting the apparatus. A Beat Frequency Oscillator of the Type 1022 is used as signal source, and the microphone built into the microphone carriage is connected to the Microphone Amplifier Type 2603. The sample under examination is inserted at the end of the tube and when the equipment is operated, standing waves are produced within the tube. The maxima and minima are measured by moving the microphone carriage, the ratio between the two giving a measure of the absorption co-efficient of the sample.

To assist in a rapid reading of the co-efficient the indicating meter of the Amplifier is printed with a set of scales from which a percentage reading can be taken immediately. A replica of this is drawn at the top of Fig. 6.14 from which it will be seen that there are three ranges 0 to 100 %, 0 to 70 % and 0 to 30 %.

In order to take a reading the microphone carriage is placed at a point where the sound pressure is maximum and the amplification of the Type 2603 adjusted so that the meter pointer gives full deflection. The carriage is then moved to a position of minimum sound pressure and the absorption read from the 0—100 % scale. By increasing the amplification by 10 or 20 dB before taking the minimum reading the absorption co-efficient can be read from the 0—70 % or 0—30 % graduations.

The Standing Wave Apparatus Type 4002 is equipped with two measuring tubes covering two frequency ranges, 95 to 1800 Hz and 800 to 6500 Hz. Acoustic materials with absorption coefficients in the range 4 % to 100 % can be measured with the apparatus. Additional information can be found in the Instruction Book for Type 4002.

The absorption measurements can if necessary be made selective by adding the Band Pass Filter Set Type 1612 to the Microphone Amplifier as "External Filter".

Frequency Response Recording of Loudspeakers.

Loudspeaker tests may be carried out either in an anechoic chamber, or in the open air. In the open air, noise is generally present, and a completely sound absorbent room should preferably 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 20ooo 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.

The loudspeaker under test should be fed with a constant voltage or current, the latter producing a mechanical force of constant amplitude which is applied to the diaphragm.

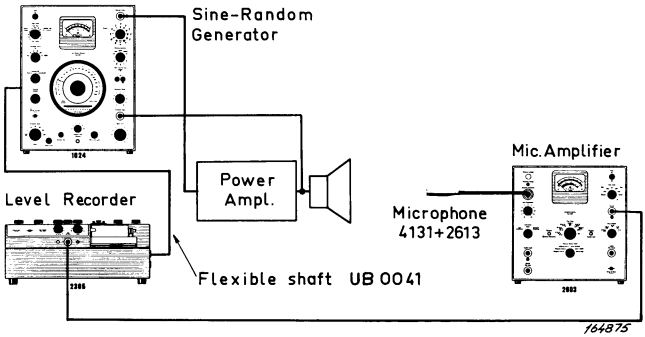


Fig. 6.15. Measuring arrangement used for recording the frequency characteristic of a loudspaker.

Fig. 6.15 shows a set-up for recording the frequency characteristic of a loudspeaker. The loudspeaker is fed from the Sine-Random Generator via a power amplifier, and in cases where the output impedance of the power amplifier is not sufficiently low, the voltage across the loudspeaker terminals can be held constant by means of the compressor circuit of the generator. The minimum compressor input voltage should then be approximately o.5 volts. The signal from the Condenser Microphone is amplified in a Microphone Amplifier Type 2603 and fed to the Level Recorder.

Fig. 6.16 shows two recordings obtained with the set-up given in Fig. 6.15. Using the Sine-Random Generator in its "Sine" position and employing a Band Pass Filter Set Type 1612 makes it possible to measure automatically the harmonics generated by the loudspeaker. The Type 1612 should then be connected to the Microphone Amplifier as "External Filter" and remote-controlled

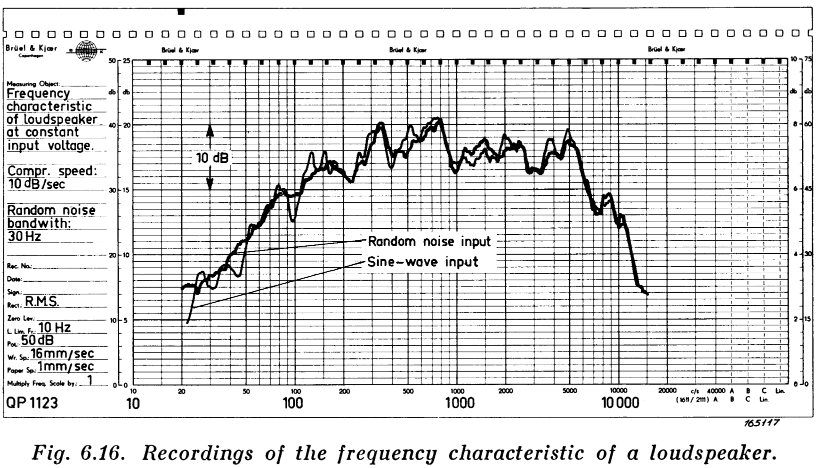


Fig. 6.16. Recordings of the frequency characteristic of a loudspeaker.

by the Level Recorder using the Remote Control Cable AQ 0002. The synchronism between the frequency calibrated paper in the Level Recorder and the Filter Set for the recording of harmonics is obtained by setting the filter switch so that it runs ahead of the frequency scanning of the Generator, the selected frequency difference being in accordance with the desired harmonic.

Instead of a Type 1612 the Frequency and Distortion Measuring Bridge Type 1607 can be inserted and use of fixed frequencies will then make it possible to carry out distortion measurements on the loudspeaker.

It should be mentioned that according to IEC Draft Recommendations the power handling capacity of a loudspeaker should be tested by means of a noise signal weighted by a low-pass filter, the specification of which is given in the Recommendation. This type of loudspeaker-test can also be carried out by means of the Sine-Random Generator Type 1024. The Combined Unit Type 3334 contains the main instruments for complete tests on loudspeakers, i.e. a Generator, a Microphone Amplifier and a Level Recorder.

Frequency Response Recording of Microphones.

Fig. 6.17 shows a typical arrangement for automatically recording the frequency response of a microphone.

In the set-up depicted, the microphone to be tested is connected to the Level Recorder Type 2305, via a Microphone Amplifier Type 2603, the originating sound source being a loudspeaker which is fed from the B.F.O. Type 1022.

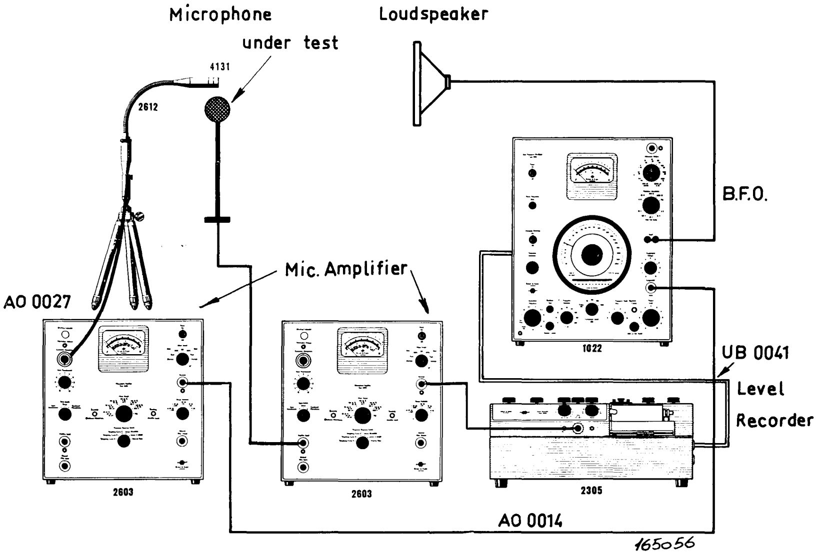


Fig. 6.17. Measuring set-up for automatic recording of the frequency response of microphones.

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 Microphone Amplifier Type 2603, the output of which is fed to the COMPRESSOR INPUT of the B.F.O. 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.

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

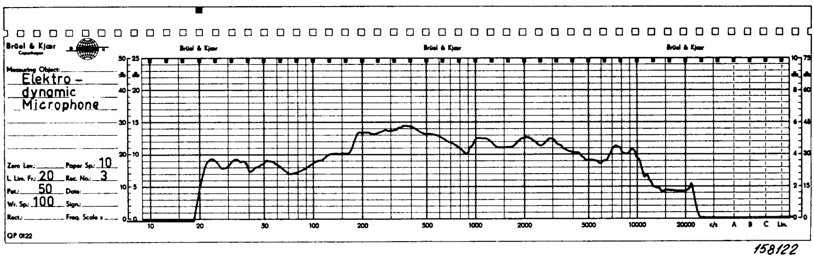


Fig. 6.18. Recording made with the set-up shown in Fig. 6.17.

C. MECHANICAL MEASUREMENTS

Vibration Measurements.

Using one of the Accelerometers Type 4312—4315 and the Vibration Pick-up Preamplifier Type 1606 or Cathode Follower Type 2612, 2613, 2614 or 2615 vibrations in buildings, machinery, ships, etc. can be readily measured. The Preamplifier 1606 can be switched to measure acceleration, velocity or displacement as desired.

In Fig. 6.19 is shown a set-up for vibration measurements on the base of a motor. The output voltage from the Accelerometer is fed to the CONDENSER MICROPHONE input socket of the Microphone Amplifier 2603, via a Preamplifier 1606. As previously mentioned the necessary voltages for the operation of the Preamplifier are supplied from the Microphone Amplifier.

The INPUT SWITCH of the 2603 should be set to position "Condenser Microphone" and the FREQUENCY RESPONSE SWITCH to position "Linear

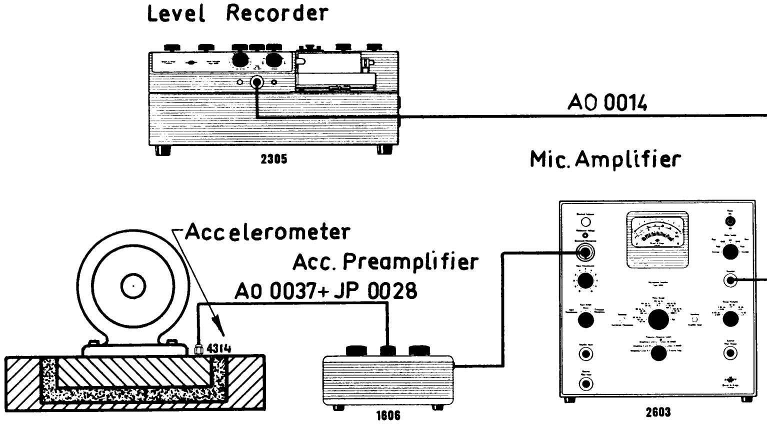


Fig. 6.19. Set-up for vibration measurements on the base of a motor.

2—40ooo". Information as to calibration of the set-up is given in the manual for the Preamplifier 1606.

If desired the vibration can be recorded on a Level Recorder Type 2305, this being connected to the output socket of the Amplifier marked RECORDER.

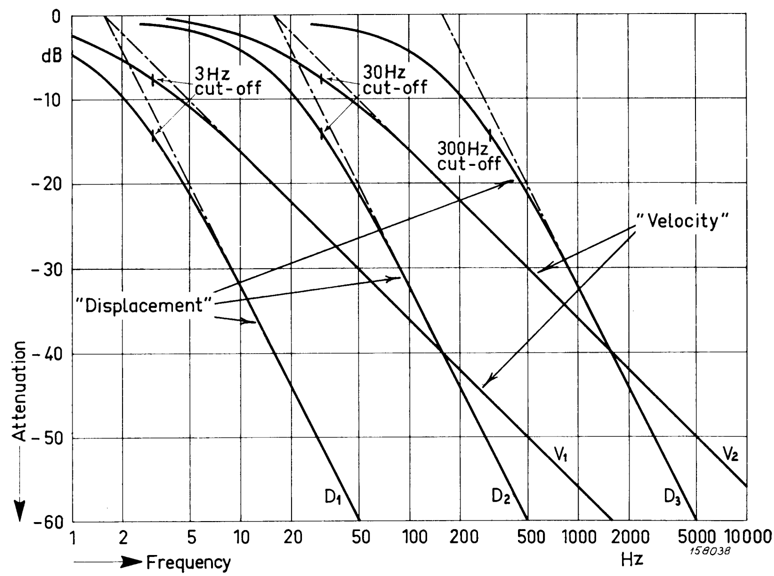


Fig. 6.20. Attenuation characteristics of the integration networks in Preamplifier Type 1606.

An indication of the vibrations over any desired period can then be obtained. By means of the integration networks of the Preamplifier 1606 it is possible to get an idea of the dominating frequencies of the vibrations measured. The attenuation characteristics of the networks are shown in Fig. 6.20. The curves marked V_1 and V_2 refer to the filters used for velocity measurements, while the curves marked D_1, D_2 and D_3 are valid for the filters used for displacement measurements. For example, if the dominating frequency of the vibrations is 1000 Hz the recorded level with the filter corresponding to curve D_3 switched in will be approximately 33 dB lower than the level recorded with the filter not inserted (i.e. with the switch marked SENSITIVITY PER VOLT on the top panel of the Preamplifier in position "Acceleration"). With a vibration frequency of 100 Hz the difference in level between a direct acceleration measurement and a measurement with the filter corresponding to curve D_3, is approximately 5 dB. Insertion of the next filter (curve D_2) reduces the level a further 28 dB.
Fig. 6.21 shows a recording obtained from measurements carried out on a system as shown in Fig. 6.19. The dominating frequency here is approximately 50 Hz, but some higher frequencies are also present. This can be seen by comparing the levels recorded for the various D-characteristics with the level of the acceleration, and by employing the curves shown in Fig. 6.20.
The determination of the dominating frequencies in the vibrations measured can be made more accurate by connecting the Band Pass Filter Set Type 1612 to the Microphone Amplifier as an "External Filter", controlled by the Level Recorder as previously described. The vibration level measured as "Acceleration", "Velocity" or "Displacement" can now be continuously recorded in octave or 1/3 octave steps on frequency calibrated paper.

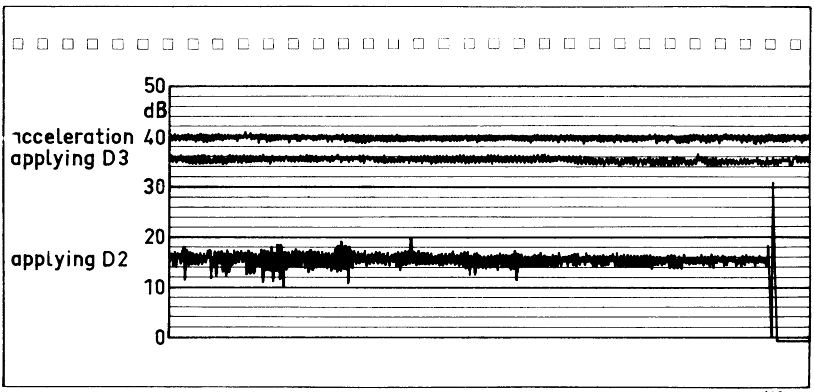


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Fig. 6.21. Recording carried out by the arrangement in Fig. 6.19. The integration networks of the Preamplifier being employed to determine the dominating frequency of the vibrations.

Measurements of Mechanical Strain in Objects Subjected to Vibrations.

In the measuring of mechanical strain on vibrating objects it is essential that the vibration excitation is kept constant within the range of frequencies at which measurements are being taken, i.e. that inherent resonance in the system has no effect on the magnitude of the driving force.

Fig. 6.22 shows a test arrangement for strain measurements on small mechanical constructions. The object under test is placed on a shaker table which is electrically driven from the B.F.O. 1022 section of the Automatic Frequency Response Recorder Type 3308.

To keep the acceleration constant a servo control system is utilized. This system consists of an Accelerometer Type 4314 mounted on top of the test object. As the acceleration has to be constant and under control the accelerometer output is connected via a Preamplifier Type 1606 and a Microphone Amplifier 2603 to the COMPRESSOR INPUT of the B.F.O. The switch on the top panel of the Type 1606 is set to position "Acceleration" and the FREQUENCY RESPONSE SWITCH of the Type 2603 to position "Linear 20—40ooo".

By using the built-in meter of the Amplifier Type 2603, the output voltage of the Accelerometer can be observed and the acceleration calculated from the Accelerometer's sensitivity curve.

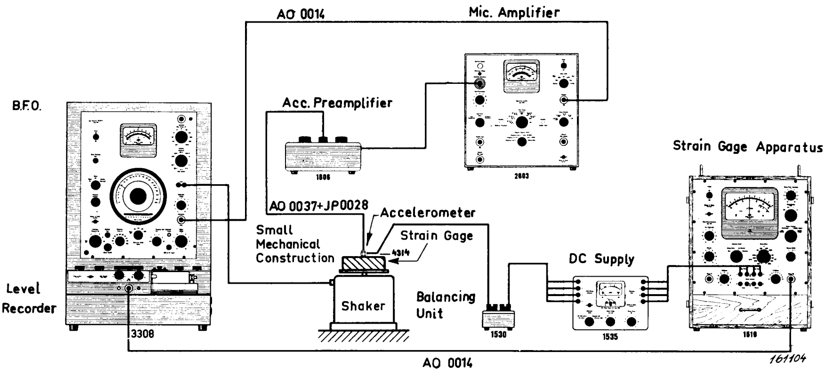

Fig. 6.22. Set-up for measurement of vibrations in small mechanical constructions.

To measure the mechanical strain in the object under test a resistance strain gage is used. This is a pick-up device which is comprised of a looped resistance (or resistances) sandwiched between insulating material which is cut in the form of a strip, and which can be glued on to the test object. The object when subjected to mechanical strain will alter the gage resistance, the alteration being registered by a sensitive measuring bridge arrangement such as the Strain Gage Apparatus 1516 + the DC Bridge Supply Unit 1535. (For further information refer to the manual for Type 1516).

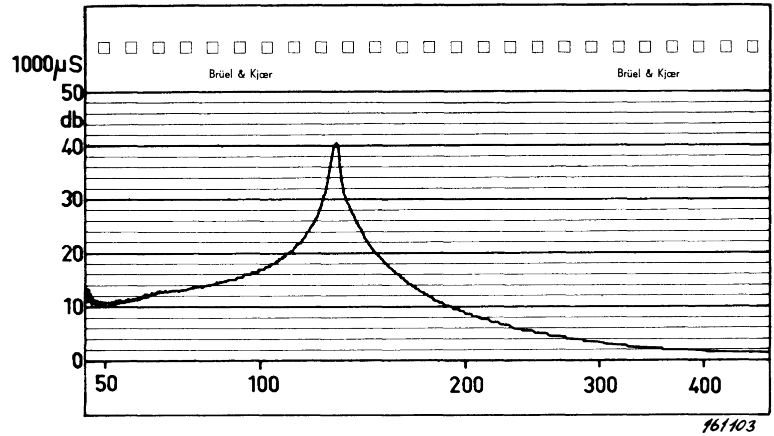

Fig. 6.23. Recording of the mechanical strain on a thin bar, measured with the arrangement in Fig. 6.22.

The output voltage from the Strain Gage Apparatus is then fed to the input of the Level Recorder of the Type 3308 to give an automatic recording. An example of such a recording, taken on a thin metal bar, showing the mechanical strain and indicating its resonance frequency is shown in Fig. 6.23.

Measurement of Microphony in Tubes.

A layout which can be used to measure the microphony in tubes is shown in Fig. 6.24. The tube and an Accelerometer Type 4314 are symmetrically

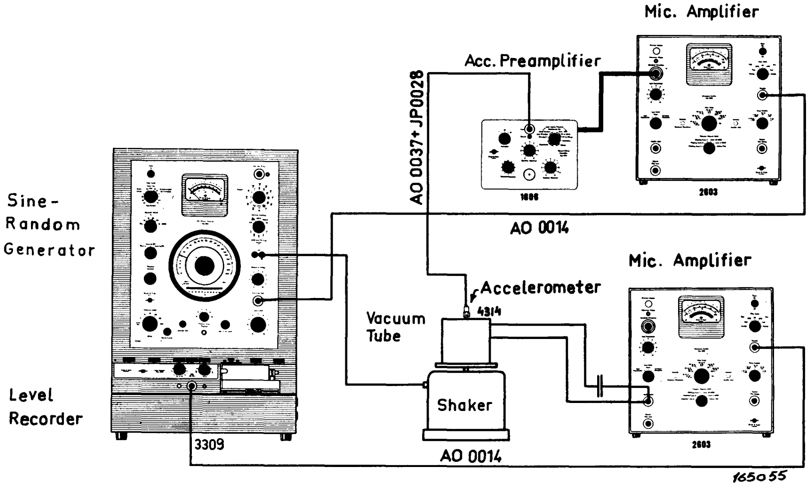

Fig. 6.24. Layout for the measurement of microphony in tubes.

mounted on a shaker which is driven by the Generator section of the Frequency Response Recorder Type 3309. The output voltage from the Accelerometer is fed to the COMPRESSOR INPUT of the Sine Random Generator by means of a similar circuit to that which is described in Measurement of Mechanical Strain. By this means the vibrating force acting on the tube is kept constant.

In Fig. 6.25 is shown a diagram of a circuit which is used in the measurements on a Philips tube ECC82. The AC voltage developed across the anode load is fed to the input of the Level Recorder section of the Type 3309 via one of the two Microphone Amplifiers Type 2603. The FREQUENCY RESPONSE SWITCH of this Amplifier is set at "Linear 20—40ooo".

Fig. 6.26 shows a recording made on a set-up as described, with the Generator in its "Sine" position.

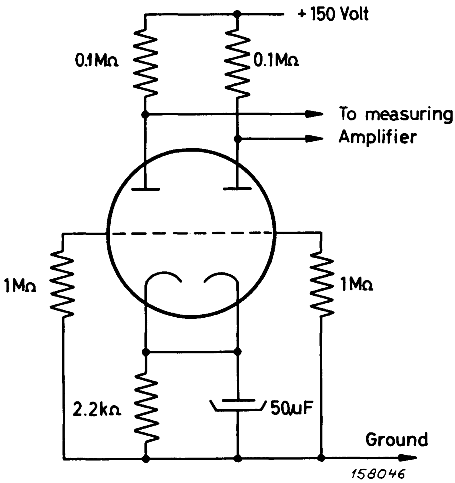

Fig. 6.25. Circuit diagram for measuring the microphony of a Philips Type ECC 82 tube.

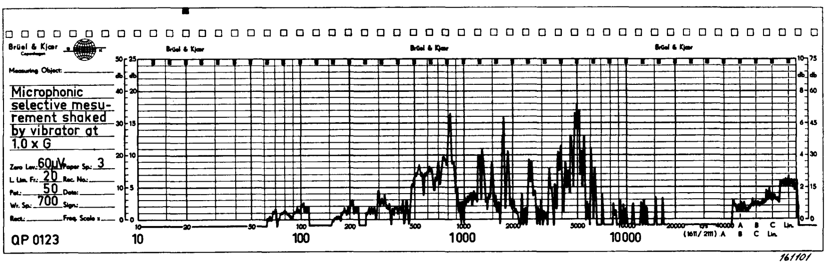

Fig. 6.26. Recording of the measurements carried out on the ECC 82.

Frequency Response and Cross-Talk Measurements on Stereophonic Systems. In stereophonic systems, automatic measurements of the frequency response of the left and right hand channel can be recorded in one sweep by utilizing a two channel method. Cross-talk between the left and right channel can also be investigated automatically. For making these measurements on, for example, a micro-groove stereophonic reproducing head, instrumentation as displayed in Fig. 6.27 can be used. The test (reference) signal source used is the B & K Stereophonic Gliding Frequency Recording Type QR 2009 which excites the transducer under examination. The left and right hand signals are applied to the Two Channel Selector section of the Response Test Unit Type 4409.

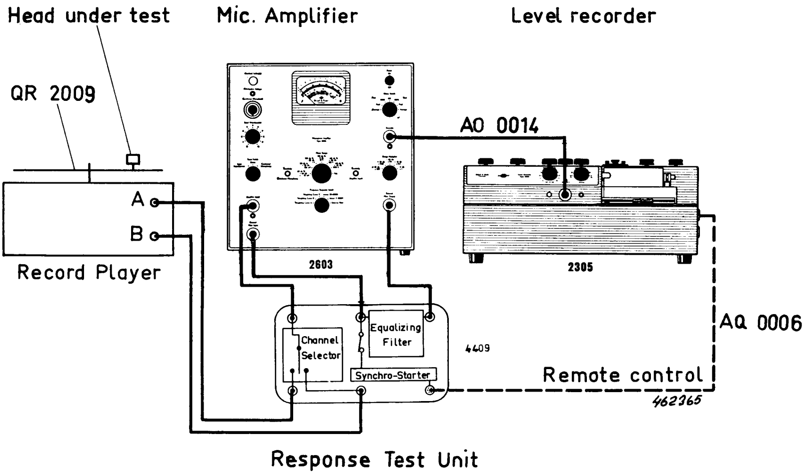

Fig. 6.27. Measuring set-up for automatic plotting of the frequency response of a stereophonic record player.

The output of this section is fed to a Microphone Amplifier Type 2603 and the equalizing filter is used as "External Filter" for the Amplifier. From the Amplifier output terminal RECORDER the signal is fed into the Level Recorder Type 2305, if desired via the Band Pass Filter Set Type 1612 for selective measurements. The Remote Control Cable AQ 0006 interconnects the Level Recorder, the Response Test Unit and the Band Pass Filter Set providing the paper drive control of the Level Recorder and filter switching of the Filter Set, if used, as well as the power supply for the Type 4409.

On the record are cut several gliding frequency sweeps. A 1000 Hz synchronizing signal is recorded before each separate sweep. At the moment where the 1000 Hz signal ceases and the sweep commences, the paper-run on the Level Recorder is started via the Response Test Unit. In this manner the preprinted frequency calibration on the recording paper will be in synchronism with the

frequency from the gliding sweep. Dependent on which track is used on the Record the reproducing head can be excited by four different modulation forms, i.e. 45° left (A), 45° right (B), lateral (A + B), vertical (A — B). By employing the two first tracks cross-talk measurements from channel left to channel right and vice versa can be carried out. Utilizing the third and fourth tracks, comparative frequency response measurements can be made. The desired test signal characteristic, Linear, IEC curve 2 or IEC curve 3 is chosen by a switch on the Response Test Unit. In frequency response measurements it is advantageous to use the Two Channel Selector of the Response Test Unit Type 4409 as the characteristics of both channels are then recorded during one sweep.
Fig. 6.28 shows a result obtained by means of the set-up in Fig. 6.27, where the Two Channel Selector has been used.

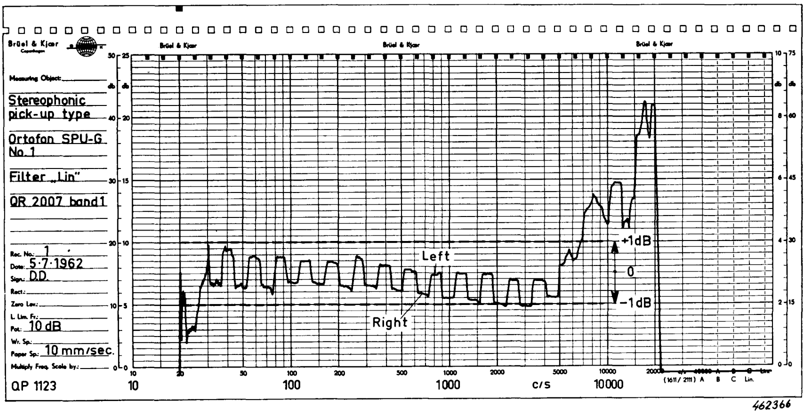

Fig. 6.28. Typical experimental result obtained by means of the set-up of Fig. 6.27. (Test of a high quality stereophonic head presenting a certain unbalance). The total duration of one plot is 35 sec. between the instant when the pick-up is put down on the record and the instant when the set-up is ready to start a new plot.

Selective equipment is required when cross-talk measurements are desired on systems where the signal in the unmodulated channel is more than 20 dB below the signal in the modulated channel.
In Fig. 6.29 is reproduced a cross-talk and frequency response recording carried out on a reproducing head. The Two Channel Selector section was not working automatically here as the signal of the modulated channel (left) was recorded first. After reversing the recording paper the cross-talk signal in the unmodulated channel (right) was recorded subsequently, with the Channel Selector section in the right channel position. Owing to the characteristic response obtained when using the Band Pass Filter Set in

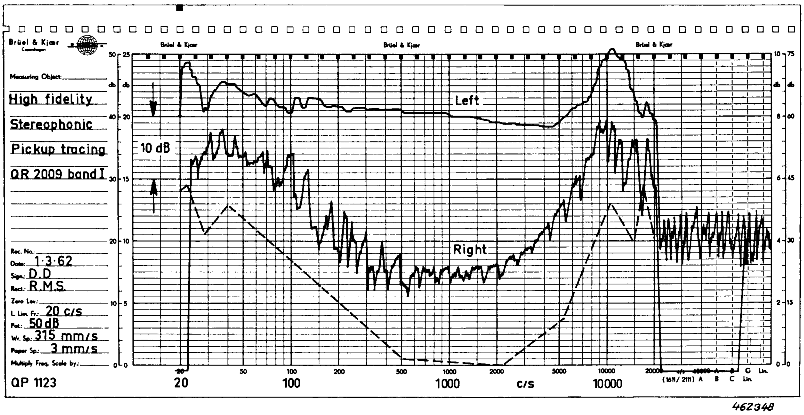

Fig. 6.29. Recording of cross-talk measurement on a high fidelity stereophonic microgroove reproducing head. The dashed line, seen on the recording, is the limit of cross-talk discrimination measurable by the equipment. The signals above 20000 Hz are wide band background noise levels from the Record.

selective measurements, employing sweeped test frequency signal, the top points of the second recording represent the signal level in the unmodulated channel.

Complex Modulus Measurements.

An important step in the reduction of noise and vibrations from mechanical constructions is to cover the various metallic parts with damping materials or to construct the parts directly from high polymer plastic materials which already have high internal damping characteristics. It is obviously advantageous to be able to objectively measure the elastic properties of these materials, which are dependent upon the dynamic modulus of elasticity of the material and its damping factor, i.e. complex modulus of elasticity.

The dynamic modulus of elasticity E^* differs from the static modulus*) as in the former the phase shift between the total stress and the strain has to be considered. The damping factor d of a material is equal to $\text{tg}\,\varphi$ where φ is the angle of phase shift at resonance. From this it is seen that the dynamic modulus E^* can be resolved into two components, a real and an imaginary one. By means of the measuring arrangement described below the real component and the damping factor can be determined.

The measuring arrangement is comprised of a mechanical and electronic section. The mechanical is made up of the Complex Modulus Apparatus Type 3930. This consists of a mechanical fixing arrangement in which the test material is clamped, and where two electro-mechanical transducers are

*) Static modulus of elasticity is equal to the ratio between p and e where p is the stress kg/cm^2 applied to a material, and e its relative elongation (strain).

positioned. A large variety of samples can be mounted in the fixture, the maximum dimensions being 12 × 12 × 220 mm. The Complex Modulus Apparatus can be placed in an environmental chamber for measurement under varying ambient conditions. It is designed for use over a wide range of temperatures from the extreme low end up to about 250°C (480°F). The electronic section, The Automatic Frequency Response Recorder Type 3329, is a combination of the B & K Beat Frequency Oscillator Type 1022, the Microphone Amplifier Type 2603 and the Level Recorder all mounted in one rack. See also part Combined Units of this book. With this equipment investigations can be carried out in the frequency range 20—20000 Hz, and the vibration response of the specimen which is clamped in the test jig can be automatically recorded on preprinted frequency calibrated paper.

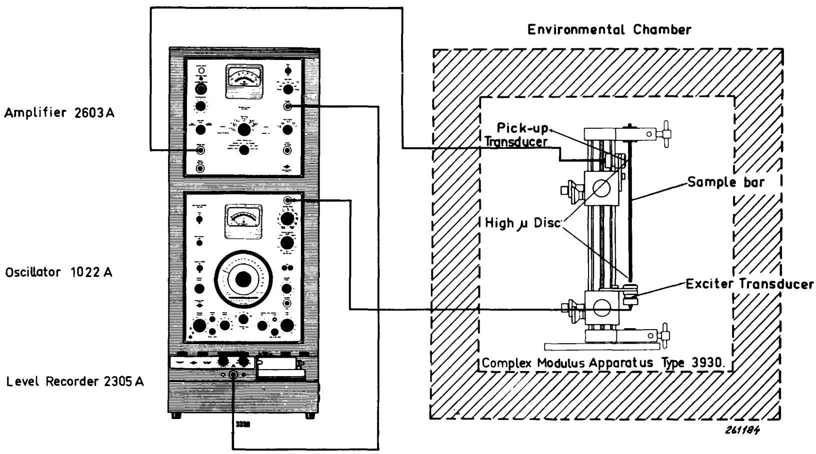

Fig. 6.30. Measuring arrangement for the determination of a material's elastic properties.

As an example a measurement is reproduced completed on a plexiglass bar having the following dimensions: width 0.8 cm, thickness 0.33 cm. The measuring arrangement can be seen in Fig. 6.30. The sample was suspended in the test jig at the upper end, whereas the lower end of the bar was left free. The length of the bar from suspension to free end was 15.3 cm. To enable excitation and signal pick-up from the sample, small pieces of razor blades were cemented on the bar at the points facing the transducers. The output voltage from the Beat Frequency Oscillator is applied to the exciter transducer and the vibration signal from the pick-up to the input of the Microphone Amplifier. The output from this Amplifier is then fed to the Level Recorder, in which a 50 dB Range Potentiometer has been inserted. By synchronizing the Oscillator scan, which is mechanically driven from the Level

Recorder, with the frequency preprint on the recording paper, the vibration response of the sample bar can now be recorded automatically as a function of frequency. The obtained result is seen in Fig. 6.31. Five modes of resonances are pronounced at approximately 37, 210, 600, 1200 and 1950 Hz, the other shown maxima are derived from harmonics in the transducers and resonances in the suspension system. The minimum at approx. 3000 Hz is due to the fact that a nodal point of the bar has been opposite the pick-up. From the width (3 dB = 0.707 points) of the individual resonance peaks and its frequency the elastic properties at the various frequencies can be determined. Investigating materials comprised of low damping, the resonance maxima will, when recorded on frequency calibrated paper, appear as relatively high and narrow peaks, resulting in an uncertain determination of the 3 dB width. By placing the Synchronizing Gear Lever 1 : 10 on the Level Recorder, out of operation a ten times higher paper speed results in a ten times wider resonance peak on the paper. In this case, of course, the frequency calibration of the recording paper cannot be used.

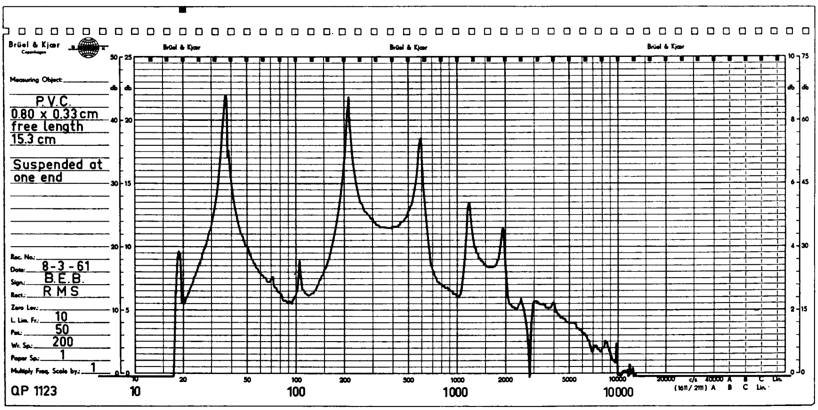

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Fig. 6.31. Recorded vibration response of a P.V.C. sample bar.

Other than 10 times paper speed multiplication can be obtained, e.g. 30 or 33.3 times employing DRIVE SHAFT II of the Level Recorder (instead of SHAFT I) for driving the internal chain of the Automatic Frequency Response Recorder and varying the speed by means of the control knob DRIVE SHAFT SPEED.

Note: The change of drive shaft mentioned for the internal chain is described in the Instruction Book for the Level Recorder.

Damping Factor Reading with Q-Rule. A direct reading of the Q-value, which is the inverse of the damping factor d, can be carried out by employing the B & K Q-Rule Type BM 1001. This enables damping factors of approximately 0.01 to 0.3 to be determined. The Q-value of a single degree of freedom and viscously damped system (equivalent to electrical series or parallel resonant circuits) can be calculated from $\frac{f_0}{\Delta f}$ where f_0 is the resonant frequency of the circuit and Δf the width of the resonant peak at 3 dB ($\times$ 0.707) below the top.

$$Q = \frac{1}{d} \simeq \frac{f_0}{\Delta f} \quad \text{when} \quad \frac{\Delta f}{f_0} \ll 1.$$

Since the recording is made with a logarithmic frequency scanning the quantity $\frac{f_0}{\Delta f}$ is in this case dependent only on the bandwidth in mm and on the scanning-rate in octave/mm.

The Q-rule BM 1001 gives direct reading of $\frac{f_0}{\Delta f}$ from the geometrical band-width of the resonance curves for the following sweep rates:

scale "10/1": 10 $\times$ 15 mm/octave
scale "30/1": 30 $\times$ 15 mm/octave
scale "33/1": 33.3 $\times$ 15 mm/octave

These sweep-rates correspond respectively to a paper speed which is 10, 30 or 33.3 times the speed of synchronism between the paper graduations and the B.F.O. frequency scale. See Fig. 6.32.

Practical Measurement.
Place the scale, corresponding to the paper speed multiplication employed, 3 dB below the top of the resonance curve. (The distance representing 3 dB is easily found from the dynamic range of the Level Recorder and the paper

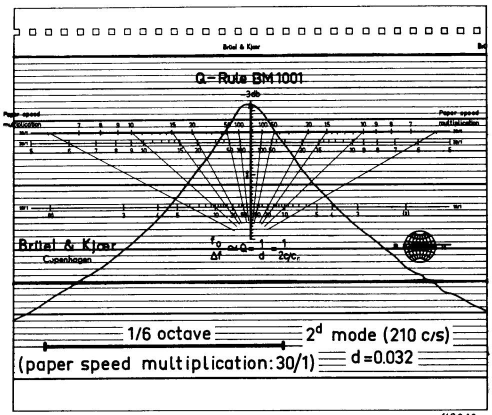

Fig. 6.32. Illustrating the use of the Q-Rule BM 1001. Paper speed multiplication 30/1.

width in use, e.g. with a 50 dB Range Potentiometer and 100 mm Paper: 3 dB = 6 mm).

Move the scale horizontally until the curve cuts the scale at equal values on each side.

In Fig. 6.32 is illustrated how the Rule is used on a resonance recording of the 2nd mode, 210 Hz, of the P.V.C. bar. The paper speed multiplication has been 30/1. By employing the respective scale of the Q-Rule a Q-value of 30 has been found. From the Q-value the damping factor d is easily found from $Q = \frac{1}{d}$, i.e. the damping factor equals $\frac{1}{30} \simeq 0.033$.

Appendix

Errors Due to Phase Distortion.

Phase Distortion. Common amplifiers will always give more or less phase distortion at their low and high frequency limits. The distortion will normally become perceptible about a decade higher than the lower frequency limit and about a decade lower than the higher frequency limit. Vide Fig. A.1(a).

The phase distortion of an amplifier has no influence on the majority of its applications as far as the signal is a pure sine-wave or pure sine-waves **with no phase relation,** i.e. when the distinct frequencies do not comprise the harmonics of a signal. If the output signal from the amplifier is rectified and measured by an indicating meter measuring the r.m.s., average and half peak-to-peak value of the signal, the phase distortion of the amplifier still has no influence on the measured result if the input signal has the character described above.

On the other hand, if the signal applied to the amplifier consists of a complex signal with a number of harmonics, (as is the case for instance with a square-wave and a triangular signal) the shape of the signal will be distorted when treated in an amplifier which has phase distortion. When the amplitude vs. frequency characteristics of the amplifier is practically straight in the range of the signal frequency-contents the number of harmonics and their original amplitude relationships are unchanged in the phase distorted signal at the output of the amplifier. If this signal is measured on the amplifier, output by the r.m.s., average and peak-to-peak measuring indicating meter, however, the following will be noted:--

R.M.S. Measuring: This is by far the most important for the majority of investigations. When using this characteristic of the rectifier circuit, the phase relation between the different components of the signal has no influence. *Therefore, by measuring a phase distorted signal by an r.m.s. measuring and indicating meter the same value will be read as for the undistorted signal.*

Average Measuring: In this case the arithmetic average value of the signal deviates from the value of the original signal when phase distorted.

Peak Measuring: When utilizing the half peak-to-peak property of the indicating meter of Type 2603 a considerable deviation from the original value is measured, when the signal is phase distorted.

Actual Variations in R.M.S., Average and Peak Reading. In Fig. A.1(b) measurements carried out on a Microphone Amplifier Type 2603 are illustrated.

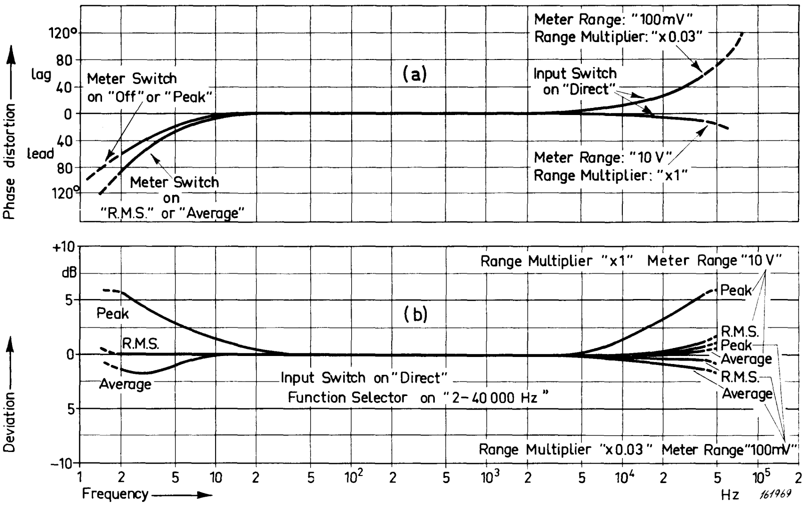

Fig. A.1. Typical characteristics of the Microphone Amplifier Type 2603.

(a) Phase response "Linear 2—40ooo". (Two separate curves represent highest expected deviation for all combinations of METER RANGE and RANGE MULTIPLIER).

(b) Variation in reading on the indicating meter for a symmetrical square-wave when switched for "RMS", "Average" or "Peak".

Fig. A.1(a) shows the phase distortion versus frequency. At the high frequencies the phase distortion is to a certain degree dependent on the setting of the attenuators METER RANGE and RANGE MULTIPLIER, therefore two curves are shown giving the highest variation in phase response for possible combinations of the two attenuator positions. In part b of Fig. A.1 is illustrated the variation in meter reading versus frequency when the Microphone Amplifier treats a symmetrical square-wave signal relative to a pure sine wave. The r.m.s. reading shows an increase at the highest frequencies which is due to an increase in the Amplifier's amplitude vs. frequency characteristic beyond the high frequency limit (40 kHz).

Shape Distortion of Signal with Harmonics. In Fig. A.2 is shown the influence of phase distortion of a symmetrical square-wave signal when treated in the Microphone Amplifier (switched to "Linear 2—40ooo") and measured on the output RECORDER. Fig. A.2(a) gives a 2 Hz signal corresponding to the low fequency limit. Fig. A.2(b) illustrates a 50 Hz signal which will be equal to the shape of the calibration voltage (Ref.) of the apparatus when it is powered from a line voltage with a frequency of 50—60 Hz. As Fig. A.2(c) shows, no perceptible phase distortion is present when the fundamental frequency of the square-wave signal is around 1ooo Hz. At the highest frequencies, however, phase distortion is again perceptible, which can be seen from Fig. A.2(d), where the distortion of a 40 kHz signal is reproduced.

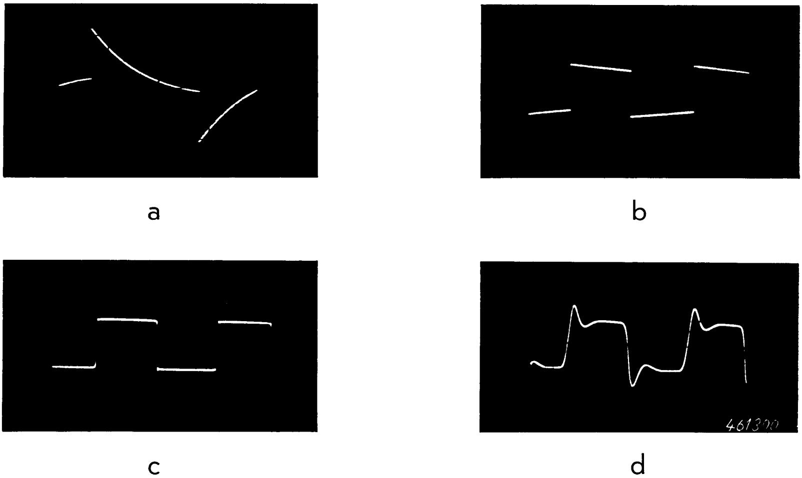

Fig. A.2. Reproduction of phase distortion of a symmetrical square-wave.
(a) 2 Hz
(b) 50 Hz
(c) 1ooo Hz
(d) 40ooo Hz

Specification

Frequency Characteristic:

"Linear": 2 Hz to 40000 Hz to within ± 0.5 dB relative to 1000 Hz
5 Hz to 20000 Hz to within ± 0.3 dB relative to 1000 Hz

Weighting Networks: Frequency response in accordance with the IEC proposed standards for precision sound level meters.

Sensitivity: Maximum 100 μV and minimum 1000 V for full deflection on the indicating meter.

Input Impedances:

1. INPUT POTENTIOMETER: approximately 0.7—1 megohm, the parallel capacity being dependent on setting.
2. AMPLIFIER INPUT: 2.2 megohm parallel with 30 pF.
3. CONDENSER MICROPHONE: 270 or 700 megohm parallel with 2.5—3 pF when one of the B & K Cathode Followers is incorporated.

Attenuators:

METER RANGE: Variable in steps of 20 dB. Accuracy within ± 0.15 dB relative to position "10 mV" and 1000 Hz.

RANGE MULTIPLIER: Variable in steps of 10 dB. Accuracy within ± 0.1 dB relative to position "× 0.01" and 1000 Hz.

Meter:

Meter Rectifier Circuits, Accuracy.

"R.M.S.", ± 0.3 dB of the read value for crest factors up to 4.
± 0.5 dB for crest factors from 4 to 5.
0 dB for sine wave.

"Average", ± 0.1 dB of the read value.

"Peak", half peak-to-peak, ± 0.2 dB of the read value.

Meter Scale: ± 1 % of full deflection for "RMS", "Average", and "Peak".

Meter Damping: "Slow" and "Fast" in accordance with the IEC standards.

The meter is totally protected against overload.

Calibration Voltage Stability: Within ± 0.03 dB for ± 10 % deviation of the power voltage.

Distortion (Input Amplifier): Within 0.1 % in the frequency range 5—40000 Hz, loaded with a load higher than 500 Ω.

Overload Indicator: Indicates by red light when output voltage of input amplifier section exceeds 4.5 volts peak approx.

Hum and Noise:

Referred to the input at total maximum gain, 100 dB. Approximately 5 μV with short circuited input.

Approximately 15 μV with open input.

Output on the Terminal RECORDER:

Voltage: 10 volts $\pm$ 2 dB for full deflection on the meter scale. Maximum available peak voltage approximately 45 volts.

Impedance: 50 Ω in series with 24 μF.

Terminal EXTERNAL FILTER INPUT:

Voltage: 1 volt max. for full deflection on indicating meter.

Output Impedance: 10 Ω approximately.

Terminal EXTERNAL FILTER OUTPUT:

Input Impedance: 1.5 megohm approximately.

Overall Amplifier Stability: Better than $\pm$ o.3 dB for a deviation of $\pm$ 10 % of power supply voltage.

Polarization Voltage: The polarization voltage for the Condenser Microphone Cartridges can be adjusted about 200 volts.

Power Supply: 100 — 115 — 127 — 150 — 220 — 240 volts AC, 50—400 Hz. Power consumption is approx. 50 watts.

Cabinets:

With the mechanical design of all B & K apparatus, it is very easy to interchange the instruments with the various cabinets. The equipments are delivered in metal cases as standard fittings which can be mounted in any desired way, i.e. mahogany cabinet or frame for 19″ standard rack.

Type 2603 A:

The Microphone Amplifier is in a metal case and is intended for laboratory use.

Type 2603 B:

Similar to Type 2603 A but the instrument and the metal case are housed in a mahogany cabinet with cover. In this cabinet it is easy to transport the instrument.

Type 2603 C:

Similar to Type 2603 A but it is supplied in a frame ready for mounting the instrument in a 19″ standard rack.

Dimensions:

Excl. dials and knobs	*Height*	*Width*	*Depth*	*Weight*
Type 2603 A	38 cm 15 inches	38 cm 15 inches	20 cm 8 inches	12.5 kg 27.6 lbs
Type 2603 B	40.5 cm 16 inches	40.5 cm 16 inches	27.3 cm 11 inches	16.5 kg 36.5 lbs
Type 2603 C	44.2 cm 17 inches	48.2 cm 19 inches	20 cm 8 inches	12.5 kg 27.6 lbs

Accessories Included:

4 screened plugs JP 0018
Fuses and lamps.

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