4712

INSTRUCTIONS AND APPLICATIONS

Frequency Response Tracer Type 4712

The Frequency Response Tracer is designed especially for quality control of electro-acoustic devices. Together with a B & K Beat Frequency Oscillator Type 1022 it makes possible fully automatic, easily operated test systems, suitable for checking the frequency response of microphones, loudspeakers, hearing aids, tape recorders, audio-frequency filters etc. in the frequency range 20—20ooo Hz.

Accelerometers
Acoustic Standing Wave Apparatus
Artificial Ears
Artificial Voices
Audio Frequency Response Tracers
Audio Frequency Spectrometers
Audio Frequency Vacuum-Tube Voltmeters
Automatic A. F. Response and Spectrum Recorders
Band-Pass Filter Sets
Beat Frequency Oscillators
Complex Modulus Apparatus
Condenser Microphones
Deviation Bridges
Distortion Measuring Bridges
FM-Tape Recorders
Frequency Analyzers
Frequency Measuring Bridges
Hearing Aid Test Apparatus
Heterodyne Voltmeters
Level Recorders
Megohmmeters
Microphone Accessories
Microphone Amplifiers
Microphone Calibration Apparatus
Mobile Laboratories
Noise Generators
Noise Limit Indicators
Pistonphones
Polar Diagram Recorders
Preamplifiers
Precision Sound Level Meters
Recording Paper
Strain Gage Apparatus and Accessories
Stroboscopes
Variable Frequency Rejection Filters
Vibration Pick-ups
Vibration Pick-up Preamplifiers
Wide Range Vacuum Tube Voltmeters
Vibration Programmers
Vibration Control Signal Selectors
Vibration Control Generators
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Frequency Response Tracer

Type 4712

January 1968

Contents

0. Introduction

The Frequency Response Tracer Type 4712 is designed especially for quality control of electro-acoustic devices. Together with one of the B & K Beat Frequency Oscillators it makes possible fully automatic, easily operated test systems, suitable for checking the frequency response of microphones, loudspeakers, hearing aids, tape recorders, audio-frequency filters etc. in the frequency range 20–20ooo Hz. This range can be extended to 200 kHz by means of a mixer stage or frequency dividers, see page 26 and 33.

The frequency response of mechanical constructions may also be investigated, if transducers are available for converting mechanical vibration into electrical signals.

The frequency response of the test object is displayed for visual inspection on a large calibrated screen with a logarithmic frequency scale and selectable logarithmic or linear amplitude scales.

Apart from typical production control applications the instrument will prove useful for many laboratory purposes where components are investigated for amplitude/frequency response. The Tracer can not, however, be used on its own as a frequency analyzer since it has no frequency selective properties. It indicates the amplitude of the input signal as a function of the frequency.

The mechanical sweep of the B & K oscillators is achieved with a small electrical motor, supplied with the Tracer. This motor is installed inside the oscillator and obtains its power from the Tracer.

1. Control Knobs, Terminals etc.

Front Plate.

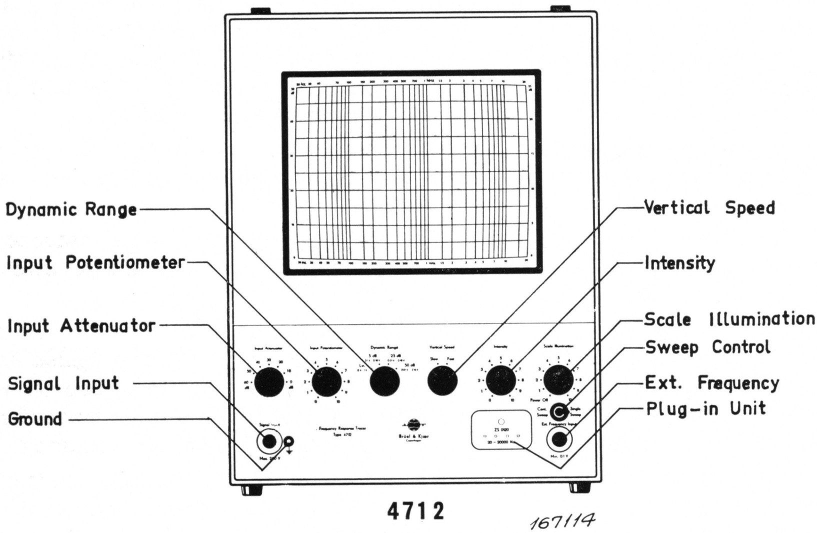

Fig. 1.1. Front plate of the Tracer.

GRADUATED SCALE Interchangeable plexiglas scales are supplied, with frequency graduation according to the plug-in unit for frequency range. Standard ranges: 200–5ooo Hz and 20–20ooo Hz.

DYNAMIC RANGE Four-position switch selecting the dynamic range of the instrument. Logarithmic 0–5 dB re 100 mV, 0–25 dB and 0–50 dB re 10 mV, or linear 0–1 V. The sensitivities indicated are for zero attenuation of the input signal.

INPUT POTENTIOMETER For fine adjustment of the input voltage to the amplifiers. Covers a range of approximately 10 dB.

INPUT ATTENUATOR	For adjustment of input voltage. Selectable in 10 dB steps from 0 to 60 dB.
INPUT SOCKET	For the input signal. Input voltage should not exceed 200 V RMS. The socket fits the B & K screened plug type JP 0018. Input impedance 100 kohm.
VERTICAL SPEED	Controls the speed with which the vertical deflection will follow a sudden change in input amplitude. "Slow" or "Fast" corresponding to rise times of 60 or 6 msec respectively.
INTENSITY	Potentiometer controlling the intensity of the trace on the screen.
SCALE ILLUMINATION AND POWER SWITCH	Potentiometer controlling the current through four bulbs for scale illumination. Also main power switch for the instrument. Power is off when the switch is turned fully counterclockwise.
SWEEP CONTROL	For controlling the sweep motor in the Beat Frequency Oscillator. Single shot or continuous sweeping.
EXT. FREQ. INPUT	For external frequency input when the input signal is noisy or when it is necessary to control the x-deflection independently. A microswitch in the socket is activated when the input plug (Type JP 0018) is inserted in the socket and switches off the internal frequency input to the frequency sensitive circuit. Input impedance 5 kohm.
PLUG-IN UNIT	Determines the frequency range of the instrument. Type ZS 0120 logarithmic 20–20ooo Hz and Type ZS 0121 logarithmic 200–5ooo Hz, are standard ranges supplied with the instrument, Type ZS 0124 linear 150–4150 Hz is delivered on special order.

Back Plate Controls.

BLANKING LEVEL	Continuously variable screwdriver operated potentiometer controlling the level below which the trace is extinguished. Covers at least the lower half of the scale.

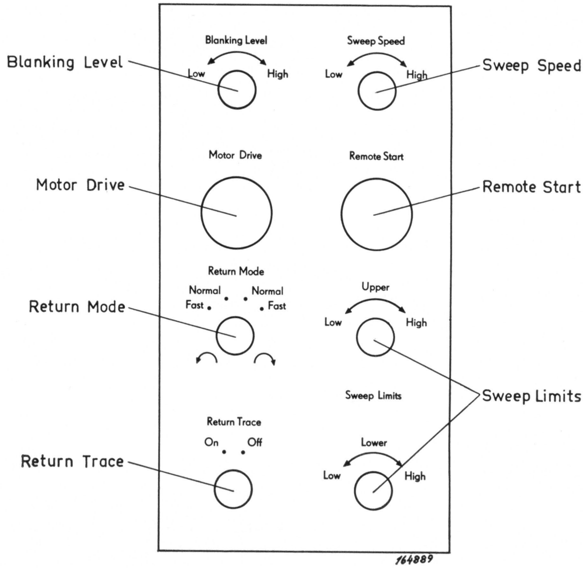

Fig. 1.2. Control panel at the back of the Tracer.

MOTOR DRIVE	6-pin socket for control of the sweep motor in the Beat Frequency Oscillator. Control cable with plugs supplied with the instrument.
RETURN MODE	Determines the return sweep from the upper to the lower frequency limit. The return may be clockwise or anticlockwise, fast or normal, depending on the setting of this switch.
RETURN TRACE	On-Off switch for the intensity of the trace during backward scanning.
SWEEP SPEED	Continuously variable potentiometer controlling the speed of the sweep motor in the B.F.O. The speed is variable from about 1/3 to 3 octaves per second.
REMOTE START	For remote control of the sweep motor. Short-circuiting the two active pins will start the motor.
SWEEP LIMITS	Continuously variable potentiometers determining the upper and lower sweep limits. Both potentiometers cover the whole frequency range so that any part can be selected for automatic scanning.

2. Operation

Principle of Operation.

The Frequency Response Tracer requires a sinusoidal signal generator for its operation. One of the Brüel & Kjær Beat Frequency Oscillators Types 1013, 1017 or 1022 is eminently suited for this, since a sweep drive motor can be built into the Oscillator and automatically controlled from the Tracer for quick testing of components on a production line.

The 1013 covers the frequency range 200–200ooo Hz, the 1017, the low frequency range 2–2ooo Hz and the 1022 covers the whole audio frequency range 20–20ooo Hz each of them in one sweep, which is very convenient for most applications of the Tracer.*)

The Beat Frequency Oscillator supplies a variable frequency signal to the test object. The output from this is fed to the input socket of the Frequency Response Tracer which gives an x-deflection proportional to the frequency of the signal and a y-deflection proportional to amplitude. Then as the frequency range is swept through, the frequency response of the test object is shown on the 14″ screen of a cathode ray tube, the large screen giving excellent resolution of details in the curve obtained.

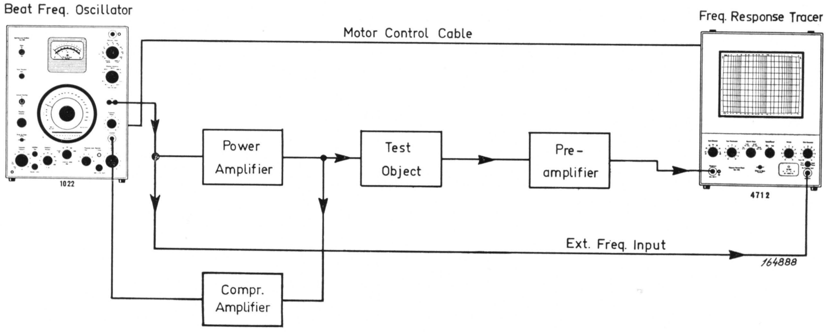

Fig. 2.1. Sketch of a typical test set-up for automatic frequency response tracing.

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*) With the introduction of the Frequency Response Tracer and the associated sweep motor, it has been found necessary to use a stronger construction of the sweep mechanism of the Beat Frequency Oscillator. If the Tracer is intended for production line purposes with continuous operation, customers are advised to order a new Oscillator even though they may already possess one. The modifications have been incorporated in all the B & K Oscillators as from April 1964.

Before automatic operation can be realized it is necessary to install the drive motor for the Beat Frequency Oscillator. Instructions are given in Appendix A on page 27. Also make sure that the blind plug inserted in the BFO's REMOTE CONTROL socket is pulled out, otherwise the output from the BFO is shorted during part of the sweep which may result in undesired switching of the sweep directions.

Setting up.

The setting up of the instrumentation depends entirely upon the kind of test to be performed, so that only a general outline can be given here. See the chapter on applications for some examples on different practical set-ups. The sketch given in Fig. 2.1 indicates the most common components of a test set-up, but all of these may not be necessary in any particular case.
The purpose of the various instruments and connections in this set-up are as follows:

Signal Generator.

Supplies the input signal for the test object as well as an external frequency signal to the Tracer when the output signal from the test object is noisy or badly distorted.
The applied generator is the B & K Beat Frequency Oscillator Type 1022 equipped with a sweep motor for automatic operation. Frequency range 20–20ooo Hz.

Power Amplifier.

Used for vibration tests but seldom necessary for electro-acoustic devices as the output impedance of the Beat Frequency Oscillator can be selected according to the input impedance of the test object, and it can supply up to about 2.5 watts power.

Compressor Amplifier.

The compressor amplifier is used in connection with the compressor circuit of the BFO for keeping the input voltage to the test object constant over the frequency range.

Preamplifier

This amplifier may be required when the output from the test object can not be loaded with an impedance as low as 100 kohm (input impedance of the Tracer), or when the signal is too weak. Otherwise the output can be taken straight to the Tracer input socket.

Motor Control Cable.

This cable, which is delivered with the Frequency Response Tracer is necessary for the power supply to, and the sweep control of, the motor installed in the BFO.

Test Procedure.

1. Set up the test instrumentation as required. (See the chapter on Applications for typical examples.)
2. Before switching on make sure that the voltage selector at the back of the instruments are set to the correct mains voltage.
3. Adjust for a suitable output voltage from the oscillator, set DYNAMIC RANGE as required, and sweep through the frequency range manually to see that the whole of the frequency response characteristic is shown on the Tracer. If there is no trace, check that the BLANKING LEVEL potentiometer at the back of the instrument is turned fully down and turn the INTENSITY knob clockwise until the spot is just visible on the screen when stationary. Then adjust the INPUT ATTENUATOR and INPUT POTENTIOMETER until a suitable amplification is obtained.
4. Set the SWEEP CONTROL switch on the Tracer to "Cont. Sweep" and the AUTOMATIC SCANNING switch on the Beat Frequency Oscillator to "Off". The upper and lower sweep limits are now set with the SWEEP LIMIT potentiometers at the back of the Tracer, checking by turning the frequency dial on the BFO manually that the sweep motor changes direction at the correct positions. Set AUTOMATIC SCANNING to "On" again.
5. Set the RETURN MODE switch to the position required for the actual test.
6. Adjust the BLANKING LEVEL potentiometer to blank off any undesired part of the lower half of the Tracer screen.
7. Switch RETURN TRACE to the required position, "On" or "Off".
8. Adjust the SWEEP SPEED potentiometer, starting with low speed and increasing until the curve is displaced in the sweep direction as much as the measuring accuracy allows for the particular test to be carried out.
9. Set VERTICAL SPEED to the desired position. "Fast" if only frequencies above 200 Hz are of interest. At 200 Hz a vertical ripple of approx. 1 dB is present in this position. At higher frequencies the ripple decreases rapidly, and at lower frequencies it increases rapidly up to 20–30 dB at 20 Hz (when 20 Hz is constantly applied to the input a vertical line of a length of 20–30 dB shows up). If the signal strength to the vertical amplifier (of a frequency above 200 Hz) is changed suddenly (e.g. by means of the INPUT ATTENUATOR), the spot will jump vertically and indicate the change after 6 milliseconds. This time delay will always be the same whatever the change to the vertical amplifier. An "overshoot" of approximately 10 per cent of the applied sudden change is normal.
   The position "Slow" should be used when also frequencies below 200 Hz are of interest to achieve sufficient readability. In this position the ripple will be approximately 1 dB at 20 Hz and the above mentioned delay will be 60 milliseconds approximately.

It is obvious that the delay will have an effect on the frequency response curve to be indicated if the sweep speed (motor speed in the BFO) is too high. When the spot moves from left to right, the curve will be to the right of where it should be, and when it moves from right to left it will be to the left.

It can be checked whether the motor speed chosen is too high by comparing the curve drawn from left to right with the one drawn from right to left. If they are not sufficiently close to each other for the specific case, the sweep speed (motor speed) should be reduced.

The instruments are now ready for automatic operation and all that is required from the operator is to place the sample to be tested in the test position, and use the sweep control switch on the Tracer.

For testing of mass produced items it may be helpful to draw in tolerance curves on the Tracer screen for easy detection of undesirable deviations from specifications. For this purpose 5 blank scales are supplied with each instrument. They are easily placed in front of the calibrated scale behind the two truncated cone nuts, but may be difficult to remove without the use of the special suction grip supplied.

3. Technical Description

A block diagram of the Frequency Response Tracer is given in Fig. 3.1. A description of its various functional blocks follows.

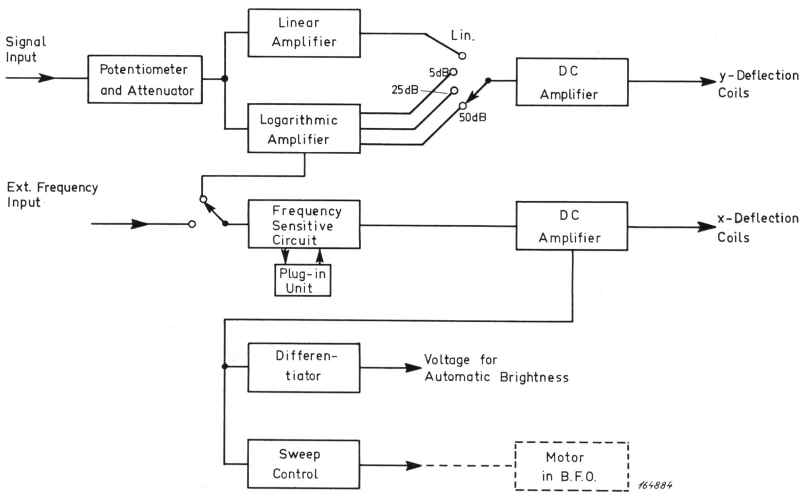

Fig. 3.1. Block diagram of the Frequency Response Tracer.

Potentiometer and Attenuator.

The input potentiometer is continuously variable over about 10 dB, while the attenuator is switchable in 10 dB steps, so that continuous amplitude control of the input voltage is obtained.*) Input voltage may range from 0 to 200 V RMS, higher voltages will dissipate too much energy in the relatively low resistance input potentiometer and should therefore be avoided.

Linear Amplifier.

The linear amplifier is a conventional design with a cathode follower in the input, voltage amplifier and phase inverter in the output. The output signals, in opposite phase, are fed to a balanced rectifier, which in connection with the succeeding filter provides a balanced output voltage proportional to the

*) Note. If signals above 50 kHz are measured, the potentiometer should be set to maximum. Otherwise the frequency response will be affected.

arithmetic average of the input signal, but the screen is calibrated to give correct RMS indication for sinusoidal signals.

The linear scale is accurate within 1 % from 1/10 to full scale. Non-linearity at the lower end is caused by diode characteristics.

Logarithmic Amplifier.

The Logarithmic Amplifier is designed to give an output which is proportional to the logarithm of the input voltage, in the graph Fig. 3.2 this is shown as a straight line. Also the output from a linear amplifier is indicated on the graph. To convert the curved line into the straight line a number of linear amplitude limited amplifiers are employed in a cascade coupling. By means of the amplitude limitation the characteristic of each stage is changed into the curves J_I, J_{II}, ... J_{VI} in the graph, with horizontal spacing equal to the amplification per stage. To obtain the straight line the outputs are summed by connecting the output from each stage to one common load through resistors which are large compared to the load resistor. Choosing the correct amount of limitation and amplification per stage it is possible to obtain a sum curve $J_I + J_{II}$ .... $+ J_{VI}$ with very small deviation from a straight line, and thus the output is closely proportional to the logarithm of the input signal.

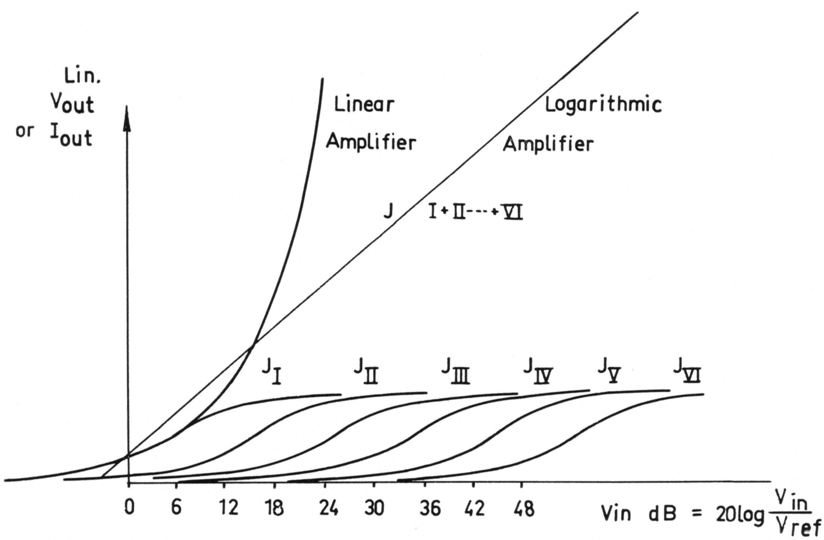

Fig. 3.2. Curves showing the characteristic of the amplitude limited amplifier stages in the logarithmic amplifier, as well as a curve indicating the characteristic of a linear amplifier and a straight line indicating the sum curve of the logaritmic amplifier.

The curves shown in Fig. 3.2 are valid for the 50 dB range of the Tracer, the spacing between the curves corresponding to 10 dB amplification per stage. The 25 dB range is obtained by reducing the amplification to 5 dB per stage. The curves J_{I}, J_{II} .... J_{VI} then have 5 dB spacing and the sum curve (straight line) will have twice the slope shown. When changing from 10 to 5 dB amplification per stage 25 dB is lost in the total amplification. To keep the same zero level, 25 dB amplification is provided by the linear amplifier.

As in some cases it is convenient to be able to observe small variations in the frequency response, the Tracer has been provided with a 5 dB range. This has been achieved by further reducing the amplification per stage to 1 dB, but as no more amplification is available, the additional loss of 20 dB causes the zero level to increase 10 times: from 10 mV to 100 mV.

Special provisions have been made to make the amplifier suitable for low frequency application. The limitation of the output from each stage is performed by saturating the stage. When a stage is saturated, the DC level at the collector is not allowed to change. This would cause charging of the coupling capacitor to the following stage and consequently a large delay for a sudden decrease of input signal would result, since the time constants of the interstage couplings have to be high. This effect has been reduced to practically zero by proper setting of the working point resulting in symmetrical clipping of the signal. Since the peak output voltage from the stage is directly proportional to the battery voltage, a reference voltage is provided for stabilization of the latter. The stability with temperature is measured to be better than o.2 % from 20° C to 50° C.

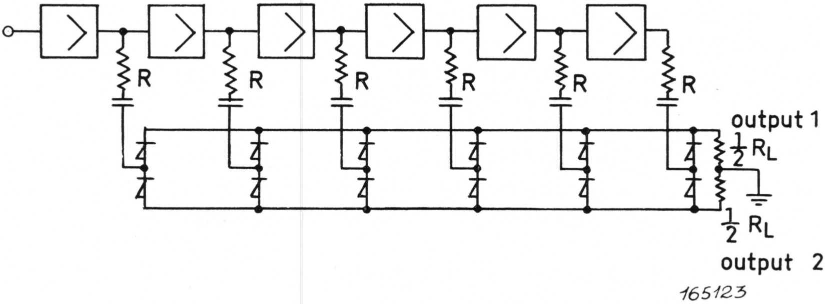

Fig. 3.3. Block diagram of the logarithmic amplifier.

Two diodes after each stage output provide symmetrical DC output in conjunction with a symmetrical common load as shown in Fig. 3.3. As each stage contains only one transistor, the output from one of the stages is in opposite phase of that from the previous stage. When the stages are saturated as the input signal increases, starting at the end stage, their contribution to ripple is minimized, because their output waveforms will be almost square. Due to the phase inversion in the stages the rectified signal ripple frequency will be mainly of twice the signal frequency.

Frequency Sensitive Circuit.

The frequency sensitive circuit provides an output voltage which is proportional to the logarithm of the input frequency. This is achieved by means of interchangeable filter networks designed as plug-in units covering various frequency ranges. As an exception the Plug-in Unit ZS 0124 has a linear frequency response for special measuring purposes (see Applications page 24). To make the output voltage independent of the input signal amplitude, a bistable multivibrator has been employed in the circuit. It switches for a very small voltage, i.e. practically at the zero crossings of the signal. An important requirement to the x-deflection is, that there must be no ripple, since a combination of X and Y ripple results in poor quality indication at the lower frequencies. This requirement comes in conflict with the demand for quick indication, which makes it impossible to use a conventional rectifier and smoothing filter causing a large delay at low frequencies.

To meet the above mentioned requirements a controlled signal rectifier has been developed, and the complete frequency sensitive circuit operates as described below: (see Fig. 3.4).

The square wave signal (a) from the multivibrator is differentiated (b), and used as inputs for two monostable multivibrators of opposite polarity. This results in the signal (c) and (d) where $\Delta t < T/2$ for the highest frequency in question. ($T = 1/f$ where f is the input frequency). Now (c) and (d) are differentiated, (e), and fed to a bistable multivibrator. As the multivibrator switches over only when the incoming pulse is of opposite polarity to the previous pulse, we obtain (f) with a delay Δt relative to (a) and the pulses (c) and (d) placed in time at the end of their particular half period, independent of signal frequency. Finally, (f) passes through a suitable high-pass filter whereby (g) is obtained, whose final instantaneous value increases with increasing frequency. The sampling of the final instantaneous value is taken care of by a gate which is controlled by the pulses (c) and (d) so that the symmetrical DC output voltages represent the final instantaneous value of the two half periods.

Between the high-pass filter and the controlled rectifier are inserted a phase inverter and an emitter follower. The phase inverter is used for subtraction of a square wave signal, (h) that is derived from (f) whereby (i) is obtained. It is seen that the final value V_2 has one polarity, and the initial value the opposite, both of about the same size. The signal (i) represents the lowest frequency in the frequency range to be indicated. With increasing frequency the 1/2 period is shortened to the left. Considering V_2 on signal (i) and assuming the period shortened, V_2 will move down the curve, pass through zero and finally at high frequencies end up with the opposite polarity but of

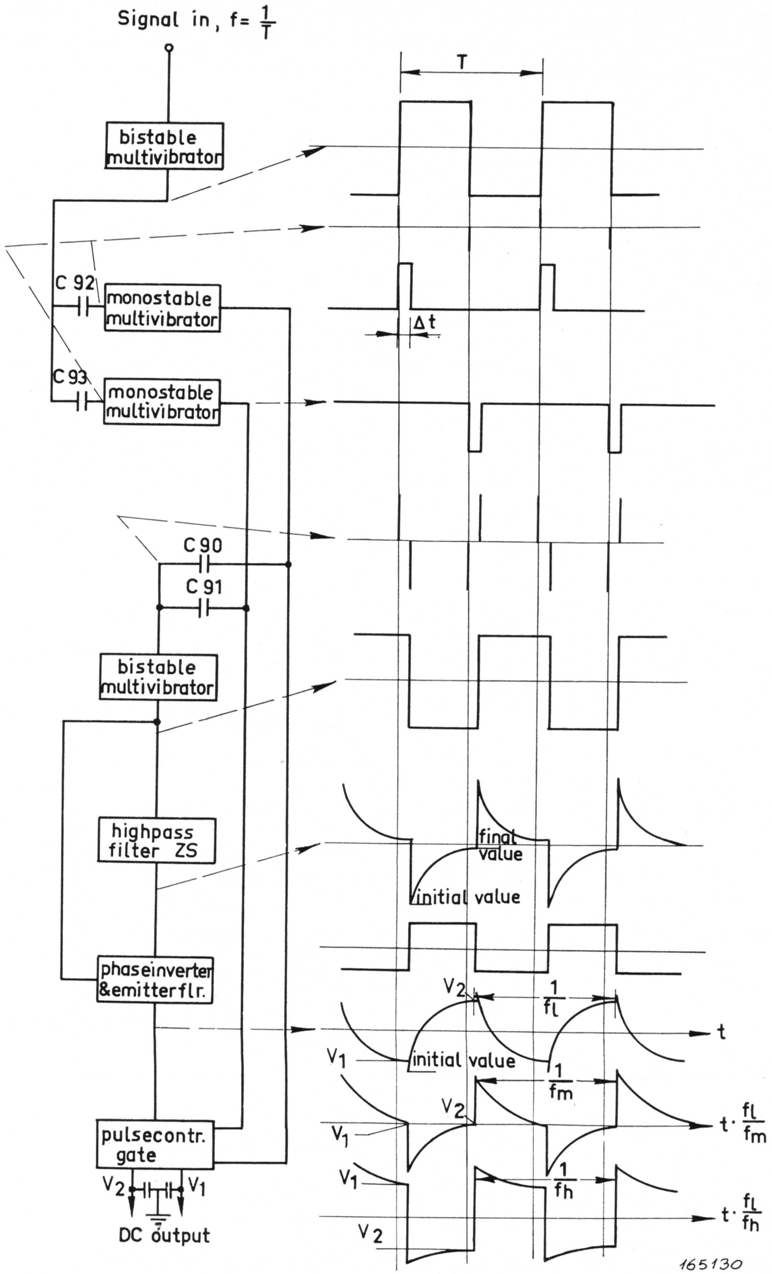

Fig. 3.4. Block diagram of the frequency sensitive circuit with the corresponding waveforms.

about the same size. The same happens to V_1. This means that V_1 and V_2 are opposite but of the same size as they were at the lowest frequency. This is just what is needed for the X-deflection coils since the neutral point of a cathode ray tube is in the middle.

The signal (k) in Fig. 3.4 represents the signal input to the gate at medium frequency f_m (scale midpoint) with expanded time scale. Signal (l) expresses the highest frequency f_h to be indicated on a time scale expanded by the same factor as the frequency with respect to (i).

The input to the frequency sensitive circuit is obtained from the logarithmic amplifier, or alternatively from an external frequency input when it is desired to control the x-deflection independently of the input signal. The plug-in unit determines the frequency range of the instrument which may be 20–20ooo Hz, 200–5ooo Hz or any other range down to one decade within 10–20ooo Hz depending on the components contained in the plug-in unit. The two ranges mentioned are "standard" and the corresponding plug-in units and calibrated scales are supplied with the instrument.*) The speed with which the x-deflection can follow sudden changes in input signal frequency is fixed at about 30 mm per period of the signal.

DC Amplifiers.

Symmetrical DC amplifiers provide the current for both the amplitude and frequency deflection yokes. Due to current feedback in the output, the current is independent of the deflection coil resistance and thereby temperature

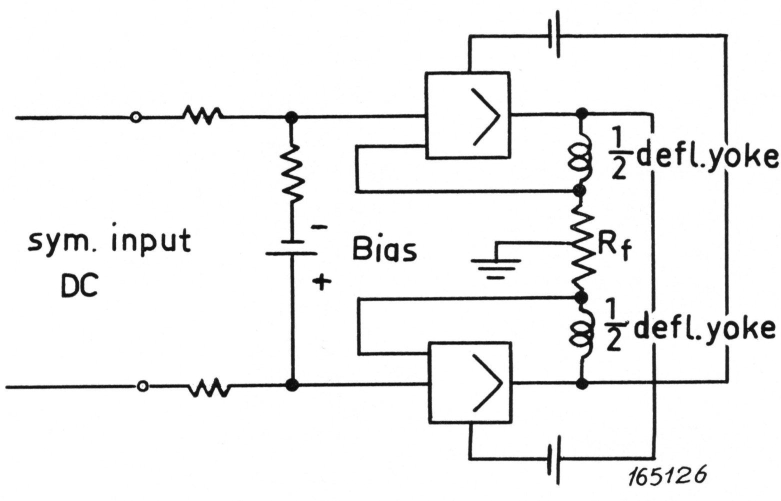

Fig. 3.5. The principle of the Y-DC amplifier.

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*) A guide to plug-in unit design for other frequency ranges is given in Appendix C.

stable. To obtain zero signal level at the bottom of the screen the Y-DC amplifier input is provided with a bias from a stable, floating DC source (see Fig. 3.5). The power supply for the DC amplifier consists of two independent voltage sources, the current from each source flowing through the total output load in opposite directions. This means that when the input signal is of the same size as the bias, but with the opposite polarity, the amplifier is in balance and the current flowing in the output load (deflection yoke and feedback resistors) is zero. When the input signal deviates from this value the current will start flowing in a direction depending on whether the signal increases or decreases. The voltage developed across the feedback resistors follows the input signal closely up to saturation of the output stage, which occurs when the current through one output transistor is zero. At the same time the current through the other output transistor will be twice the value of the current flowing through each output transistor when the amplifier is in balance. This means total drive current through the deflection yoke at maximum input voltage, and thus a high efficiency is obtained in comparison to a conventional DC amplifier.

Differentiator.
The differentiator gives an output signal which is proportional to the speed of the horizontal deflection and this is used for automatic brightness control of the trace. When increasing the sweep speed the intensity will increase within a limited range, and thus the trace brightness will appear reasonably independent of sweep speed. The automatic brightness regulation circuit can be set so that the trace is visible in the left to right direction only, or in both sweep directions. Screwdriver control for this adjustment is placed at the back of the instrument.

Sweep Limit Control.
For production line testing it is not always necessary to sweep through the whole frequency range of the instrument. When a B & K Beat Frequency Oscillator is used, with a sweep motor built in, the upper and lower limits of the frequency sweep can be set so that any part of the frequency range is scanned automatically and repeatedly. This is done with a biassed relay circuit from the x-deflection voltage. The sweep limits are set with two screwdriver operated potentiometers at the back of the Tracer. A screwdriver operated switch can be set to give fast return to the lower frequency limit, in either a clockwise or anticlockwise sweep direction.
It should be noted that the Tracer must be provided with a minimum signal 6 dB below scale zero on SIGNAL INPUT, or o.1 V on EXT. FREQUENCY INPUT for the SWEEP LIMIT control to function.

4. Applications

The possible applications of the Frequency Response Tracer are numerous since the majority of audio-frequency devices may be tested for performance with this instrument. To facilitate the setting up of instrumentation for practical investigations a few typical examples are given here.

Measuring Voltage and Frequency.

In the frequency range 20–20ooo Hz the Frequency Response Tracer will display not only the magnitude of the signal applied to its input terminals but also the frequency. In the range 20–200 kHz the magnitude can still be measured by supplying an external frequency signal of, say, 50 Hz to the EXT. FREQUENCY INPUT.*) The x-deflection will then correspond to the frequency of this signal, while the y-deflection will indicate the magnitude of the signal applied to the SIGNAL INPUT socket.**)

If it is desired to measure the frequency also in the range 20–200 kHz, a frequency divider can be employed instead of the 50 Hz signal. See passage "Frequency Scale Multiplication" Appendix C.

To find the magnitude of the input signal observe the following:

a) 50, 25 and 5 dB logarithmic amplifiers.
Turn the INPUT POTENTIOMETER fully clockwise (10) and read the deflection on the screen. The input voltage is then: (The number of dB read on the screen) + (the number of dB indicated by INPUT ATTENUATOR) 50 and 25 dB ranges re o.01 V, 5 dB range re o.1 V.***)

Example: Y-deflection 32 dB.
INPUT ATTENUATOR on 30,
Input voltage = 32 + 30 = 62 dB re o.01 volt
= 12.59 volt RMS.

b) Linear amplifier.
Turn the INPUT POTENTIOMETER fully clockwise (10) and read the deflection on the screen (0 to 1 volt). The input voltage is then: (The voltage read on the screen) × (conversion factor from the table below).

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*) A proper input plug, B & K Type JP 0018, must be used in order to activate the micro-switch in the socket, switching off the internal frequency signal.

**) It should be noted that the Tracer employs an arithmetic average type rectifier calibrated to give correct RMS readings for sinusoidal signals. If the input waveshape deviates appreciably from sinusoidal there may be an error in the measured results.

***) To convert number of dB into a ratio divide by 20 and take antilog, or use conversion table in the Appendix of this book.

INPUT ATTENUATOR setting	0	10	20	30	40	50	60
Conversion factor	1	3.16	10	31.6	100	316	1000

Example: Y-deflection 0.45 volt,
INPUT ATTENUATOR on 30 dB.
Input voltage = $0.45 \times 31.6 = 14.22$ volt RMS.

It should be noted that the vertical scale, divided by fifty equidistant horizontal lines, is the same for the 4 dynamic ranges.

Frequency Response of Amplifiers.

The Frequency Response Tracer is very well suited for checking the frequency response of amplifiers in the audio frequency range. A suitable set-up is shown in Fig. 4.1.

The amplifier under test is fed from a beat frequency oscillator and the output signal is taken to the SIGNAL INPUT terminals of the Tracer, which shows the frequency response on the screen. The functioning of tone controls etc. is easily investigated with this instrumentation.

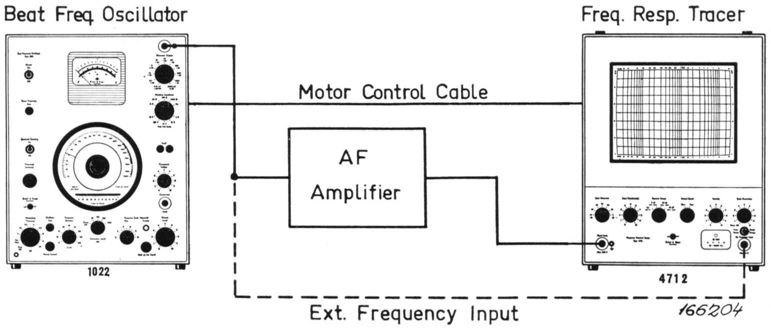

Fig. 4.1. Set-up for finding frequency response of A.F. amplifiers.

Frequency Characteristic of Tape Recorder.

The frequency characteristic of a tape recorder may be found simply by recording the frequency sweep from a Beat Frequency Oscillator on the tape and then playing it back into the Frequency Response Tracer as shown in Fig. 4.2. If the signal from the BFO is constant in amplitude the trace on the screen will be the frequency characteristic of the tape recorder.

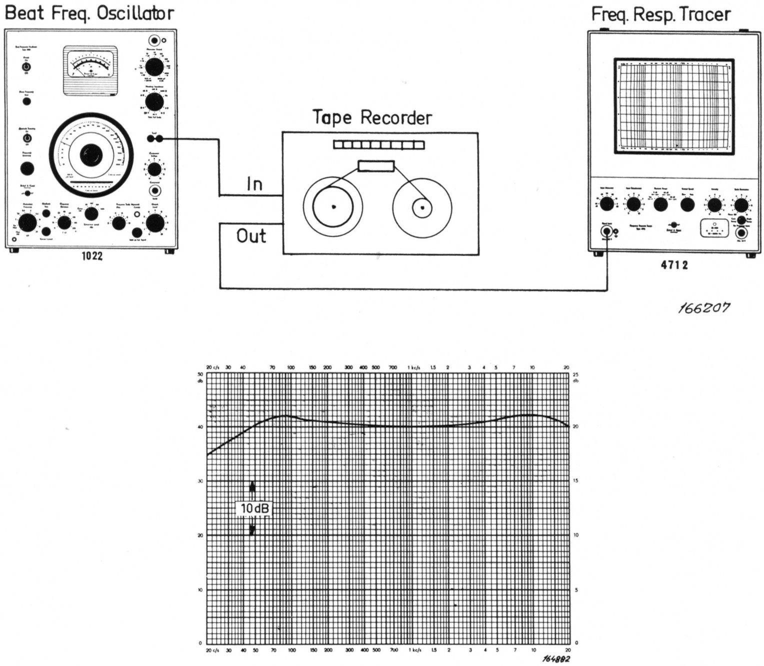

Fig. 4.2. Set-up for checking the frequency response of a tape recorder, and a typical trace as observed on the Tracer screen.

Frequency Characteristic of Hearing Aids.

The frequency characteristics of complete hearing aids can be checked when the Frequency Response Tracer is used with the Hearing Aid Test Box Type 4212. A sketch of the Test Box is shown in Fig. 4.3. It is a small anechoic chamber where the sound pressure is kept constant over the frequency range of test. The hearing aid is placed inside and the output from the earphone is measured with a precision measuring microphone, via an acoustic coupler. The frequency characteristic for the complete hearing aid can thus be recorded.

The instrumentation shown in Fig. 4.4 is suitable for automatic or manual inspection of the frequency characteristics of hearing aids.

The Beat Frequency Oscillator Type 1022 feeds the loudspeaker in the Hearing Aid Test Box. The signal from a regulating microphone placed beside the hearing aid microphone is amplified by a Microphone Amplifier Type 2603 and used for a feedback (compressor) to the BFO to keep the sound pressure level at the microphone position constant with frequency.

The signal from the BFO is also used as an external frequency input to the Tracer to give correct x-deflection even when the signal from the hearing aid is very weak or badly distorted. The output from the hearing aid earphone is picked up by a second precision measuring microphone and after amplification sent to the SIGNAL INPUT of the Tracer which indicates the frequency response of the hearing aid on the screen

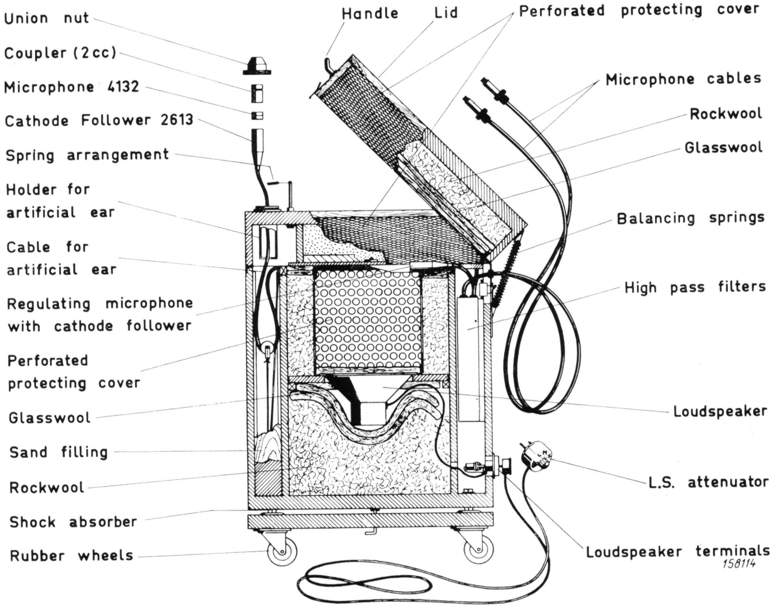

Fig. 4.3. The Hearing Aid Test Box Type 4212.

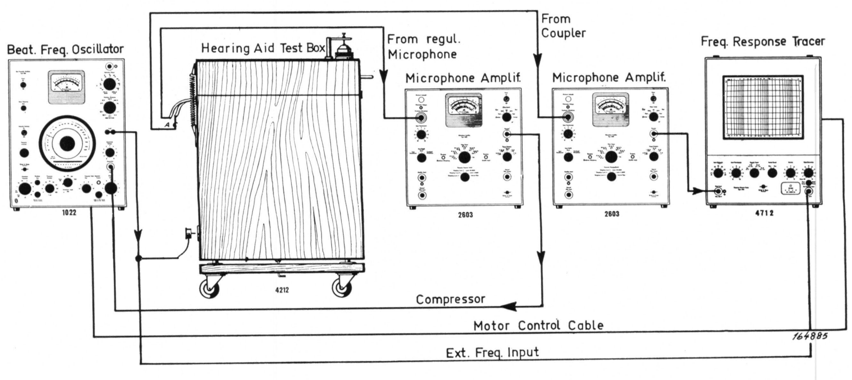

Fig. 4.4. Instrumentation used for checking the frequency response of hearing aids.

Frequency Response of Mechanical Components.

The Tracer is used with advantage when it is desired to take a quick look at the frequency response of mechanical constructions.

In vibration test programs it is often necessary to know the frequency response of a test specimen before beginning a test, in order to be able to adjust equalizing circuits for a flat input spectrum. At the same time it is undesirable to subject the specimen to vibrations before the test proper. A minimum of pre-test vibration excitation is required when the Tracer is used as indicating instrument, since it is automatically synchronized with the input frequency and can follow any sweep speed.

A set-up for finding mechanical frequency response is shown in Fig. 4.5. The Beat Frequency Oscillator Type 1022 (or Sine-Random Generator Type 1040) feeds the shaker table through a power amplifier. The vibration level is measured with an accelerometer, e.g. B & K Type 4313, and indicated by the Frequency Response Tracer.

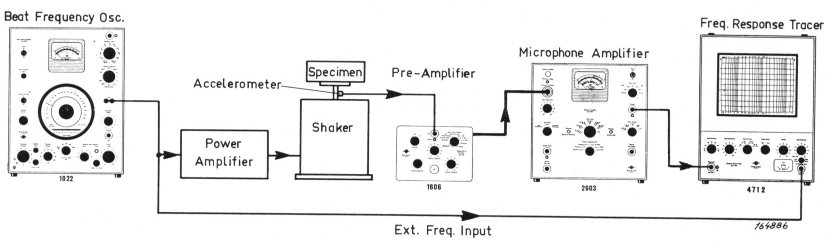

Fig. 4.5. Set-up for checking mechanical frequency response.

Frequency Characteristic of Microphones.

The frequency characteristic of microphones can be checked with a set-up as that shown in Fig. 4.6.

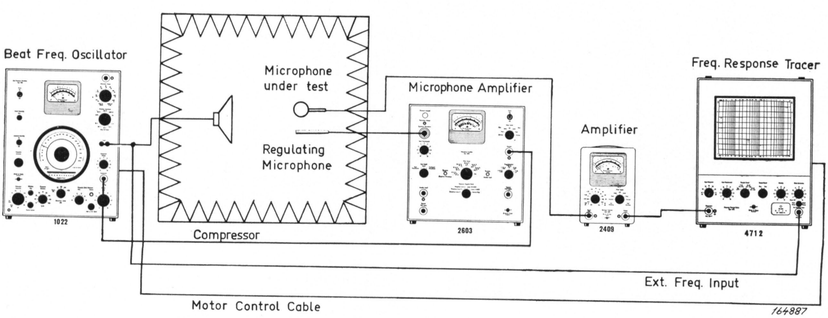

Fig. 4.6. Test set-up for automatic checking of the frequency response of microphones.

The Beat Frequency Oscillator Type 1022 feeds a loudspeaker, preferably situated in an anechoic chamber. In order to keep the sound pressure level at the microphone position constant during the frequency sweep, the compressor circuit of the BFO is used. The compressor voltage is obtained from a precision measuring microphone (e.g. B & K Type 4133 with flat frequency response from 20 to 40ooo Hz placed beside the one to be tested, using a Microphone Amplifier Type 2603. It is an advantage, but not strictly necessary, to use the signal from the BFO as an external frequency signal to the Tracer. The output from the microphone under test is amplified by an Electronic Voltmeter Type 2409 (or another Microphone Amplifier Type 2603) and then fed to the SIGNAL INPUT of the Frequency Response Tracer which indicates the frequency response of the microphone.

Frequency Characteristic of Earphones.

With the aid of the Artificial Ear Type 4152 the frequency response of earphones used with telephone equipment, hearing aids, audiometers etc. can be recorded on the tracer. A suitable set-up is shown in Fig. 4.7.

The output from a Beat Frequency Oscillator Type 1022 is fed to the earphone which is placed in the coupler of the Artificial Ear. The output from

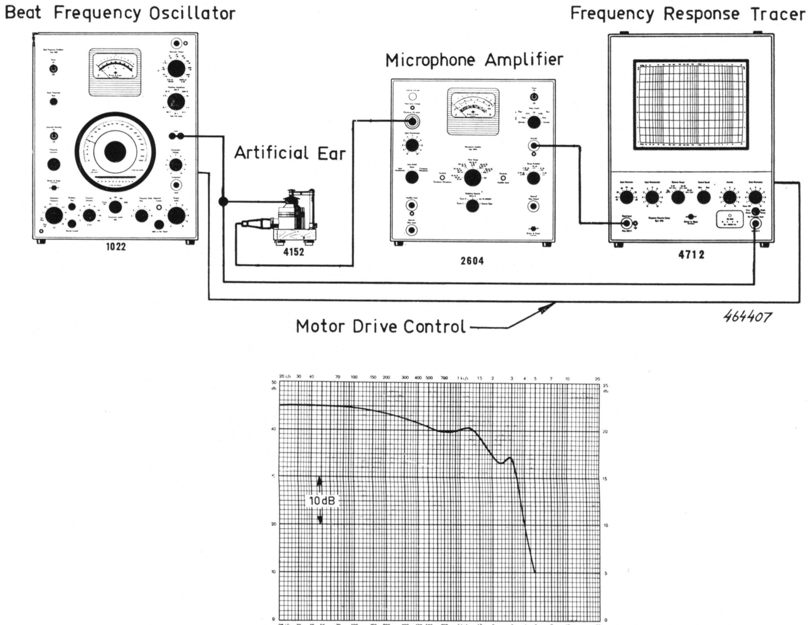

Fig. 4.7. Test set-up for checking the frequency characteristic of earphones, and a typical trace as observed on the Tracer screen.

the precision measuring microphone in the Artificial Ear is amplified in a Microphone Amplifier Type 2603 and fed to the Frequency Response Tracer, giving the frequency characteristic of the earphone on the screen of the cathode ray tube.

Automatic Testing of Telephone Sets.

The Frequency Response Tracer Type 4712 is included as an integral part of the B & K Electroacoustic Transmission Measuring System Type 3350. This Measuring system is designed for objective measurements on complete subscriber's telephone sets or parts thereof. It makes possible a continuous production check on the quality of microphone and receiver inserts with high accuracy and in accordance with international standards.

For more information see the literature for the Electroacoustic Transmission Measuring System.

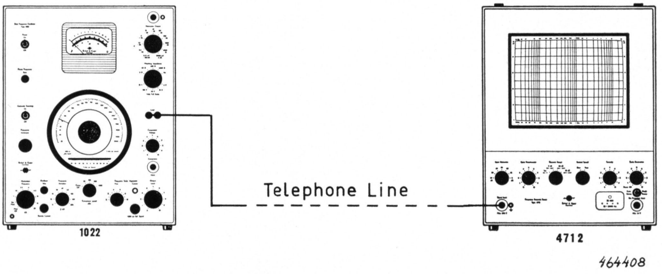

Fig. 4.8. Instrumentation used for checking the frequency response of a telephone line.

Frequency Characteristic of Transmission Lines.

The Frequency Response Tracer is an excellent means for checking the frequency response of telephone lines and other communication systems. In Fig. 4.8 is shown the set-up used for checking a telephone line.

A variable frequency signal generator (Beat Frequency Oscillator) is connected to one end of the line and the Frequency Response Tracer to the other, giving the frequency response of the line directly on the screen when the frequency range is swept through.

The output from the BFO should be of the order o.1–1 volt, and the MATCHING IMPEDANCE switch set to match the input impedance of the transmission Line. As a DC voltage is present on telephone lines, a capacitor should be inserted in series with the BFO.

Frequency Response of Narrow Band Filters and Carrier Frequency Equipment.

A special Plug-in Unit ZS 0124 with a linear frequency response from 150 Hz to 4150 Hz provides the Frequency Response Tracer with the possibilities of

sweeping a definite frequency band of 4000 Hz within the range 50 kHz–200 kHz.
The EXT. FREQUENCY INPUT which is only sensitive to frequency is used as X-input for a signal obtained from a mixer succeeded by a low pass filter, see Fig. 4.9. The frequency of this signal consists of the difference between a fixed (crystal) frequency and the frequency of the test signal. This indicates that the fixed frequency, which is used as a reference, must be altered when switching to another frequency range.

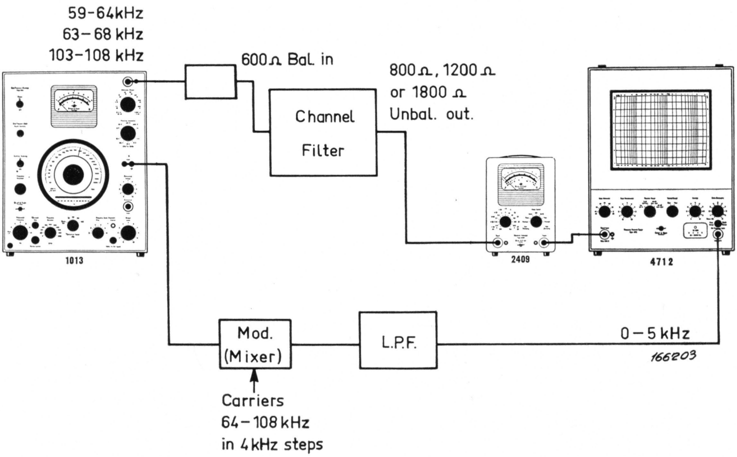

Fig. 4.9. Measuring set-up for checking 4 kHz Band Pass Filters in the frequency range 60–108 kHz.

The measuring set-up shown in Fig. 4.9 is used for the measurement of the frequency characteristic of channel filters in the ranges 60–64 kHz, 64–68 kHz etc. up to 104–108 kHz. Fixed frequencies of 64, 68 .... 108 kHz are used as the "reference" frequencies for the mixer.
As the Beat Frequency Oscillator Type 1013*) is swept (by means of the built-in wobbler) through the frequency range 64–59 kHz using 64 kHz as reference, a sweep from 0 to 5 kHz is obtained from the mixer and fed to the X-input of Type 4712. Utilizing the Plug-in Unit ZS 0124 a frequency band from 63850 Hz to 59850 Hz will be scanned from left to right on the linear frequency scale, sufficiently covering the frequency range of interest, namely 200 Hz–fc–3400 Hz (SSB modulation with audio frequency 200–3400 Hz).
A diagram of a simple example of a mixer stage followed by a low pass filter as employed in the measuring set-up of Fig. 4.9 is shown in Fig. 4.10.

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*) The Beat Frequency Oscillator Type 1013 has been modified in the following way: The wobbler has been improved so that the amplitude modulation at the largest frequency deviation (which is now ± 2500 Hz) is below 0.2 dB. When using the built-in Compressor this amplitude modulation will decrease to below 0.02 dB.

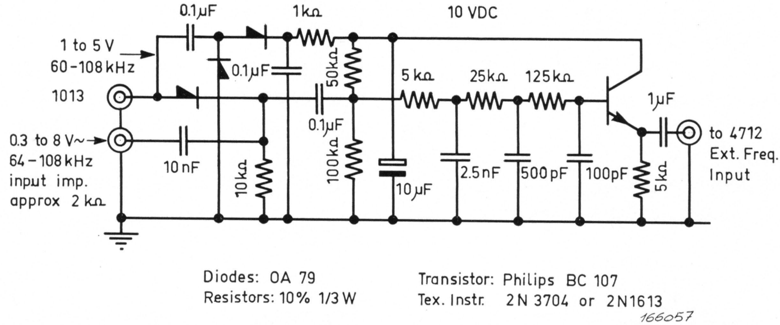
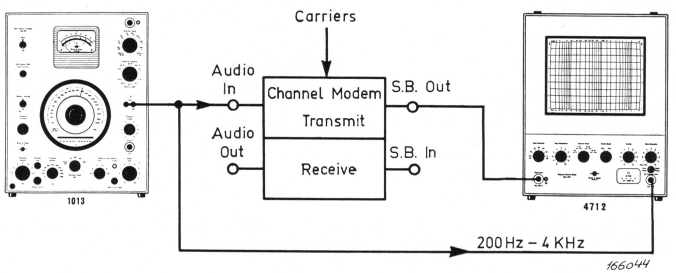


Fig. 4.10. Diagram of a Mixer Stage and a Low Pass Filter. The emitter follower is supplied with power by rectifying one of the signals.



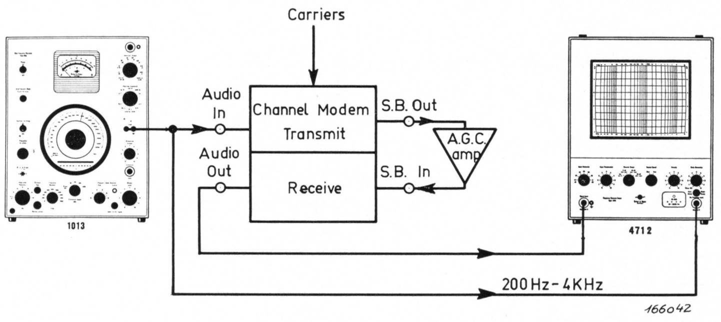


Fig. 4.11.

a) Set-up for measuring the frequency characteristics of the so called "Channel Modems" on the transmitter side.

b) Same measurement carried out on the receiver side. In this case, as it is a low frequency measurement, a logarithmic frequency scale and a corresponding plug-in unit for the tracer is used.

Appendix A

Installation of Motor Drive in BFO.

The following installation procedure should be followed.

1. Take the BFO out of its metal cabinet.
2. Facing the back of the instrument remove the left hand shaft bearing and part of the shaft shown in Fig. Aa1. If it is intended to drive the Beat Frequency Oscillator from the B & K Level Recorder Type 2305 as well as from its own motor, the right hand part of the shaft should be left in position. If the oscillator is to be used only with the Tracer ,and especially at high sweep speeds it is recommended to remove both parts of the drive shaft.
3. Mount the large wheel on the remaining part of the shaft as shown in Fig. Aa2.

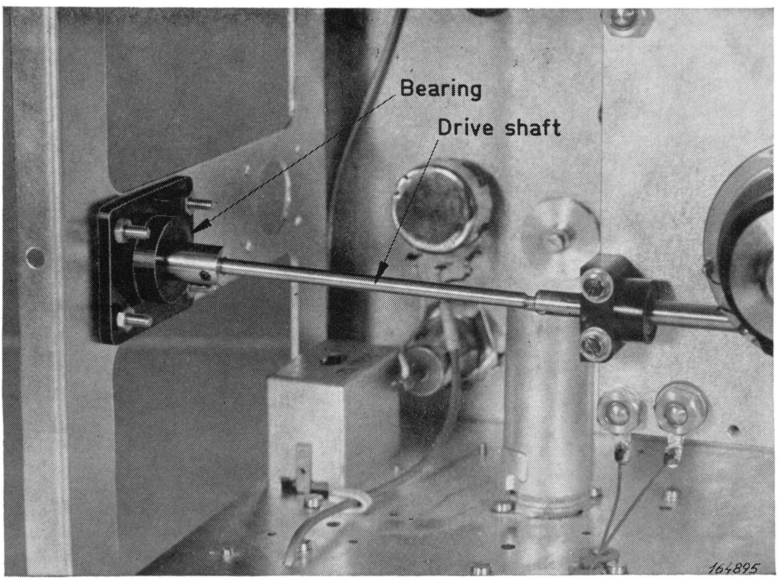


Fig. Aa1.

4. Fix the motor and its mounting plate with the two motor fixing screws as shown in Fig. Aa3. The steel ball is inserted in order to ground the large wheel.

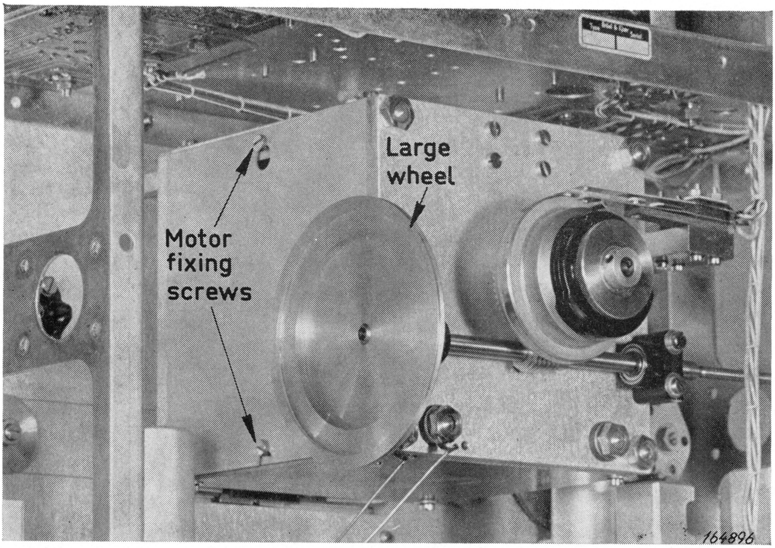


Fig. Aa2.

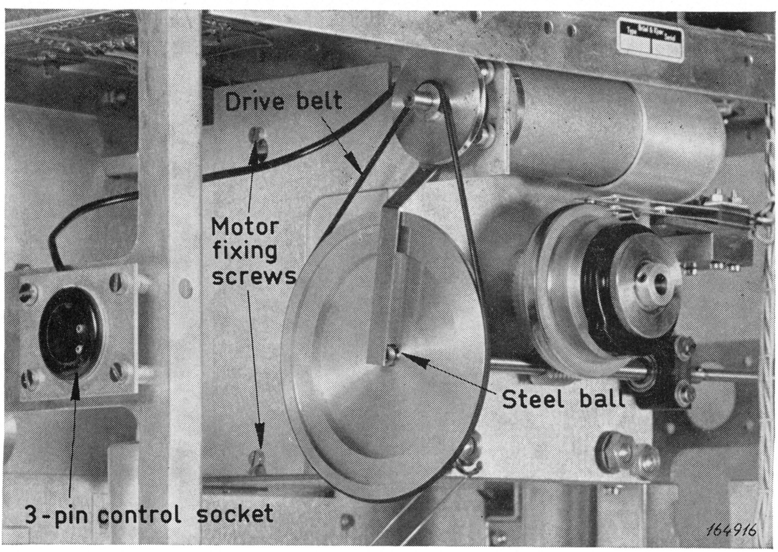


Fig. Aa3.

5. Slide the belt drive onto the two wheels. Two different speed ratios may be selected. If the scanning speed is going to be relatively high, the smallest speed ratio should be used in order to protect the motor from excessive wear (i.e. use the large track on the motor wheel and the small track on the shaft wheel).
6. Fix the 3-pin control socket as shown in Fig. Aa3.
7. Connect the Motor Drive socket at the back of the Tracer to the 3-pin control socket with the control cable supplied, and remove the blind plug inserted in the Remote Control socket at the front of the BFO. The instruments are ready for automatic operation.

Appendix B

Decibel Conversion.

The following table is given in order to facilitate the conversion from decibel (dB) to voltage ratio. It is used as follows:

Subtract the maximum whole number of n $\times$ 20 from the dB figure to be converted and use the rest to find a ratio from the table. The voltage ratio sought is then $10^n \times$ the figure from the table.

Example: Find the voltage ratio corresponding to 65.3 dB.

$65.3 = 3 \times 20 + 5.3$

5.3 gives from table 1.841

The ratio sought is $10^3 \times 1.841 = 1841$

If the figure was given as 65.3 dB re o.01 volt, then the voltage would be $0.01 \times 1841 = 18.41$ volt.

Table for Converting Decibels into Voltage Ratio.

dB	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
0	1.000	1.012	1.023	1.035	1.047	1.059	1.072	1.084	1.096	1.109
1	1.122	1.135	1.148	1.161	1.175	1.189	1.202	1.216	1.230	1.245
2	1.259	1.274	1.288	1.303	1.318	1.334	1.349	1.365	1.380	1.396
3	1.413	1.429	1.445	1.462	1.479	1.496	1.514	1.531	1.549	1.567
4	1.585	1.603	1.622	1.641	1.660	1.679	1.698	1.718	1.738	1.758
5	1.778	1.799	1.820	1.841	1.862	1.884	1.905	1.928	1.950	1.972
6	1.995	2.018	2.042	2.065	2.089	2.113	2.138	2.163	2.188	2.213
7	2.239	2.265	2.291	2.317	2.344	2.371	2.399	2.427	2.455	2.483
8	2.512	2.541	2.570	2.600	2.630	2.661	2.692	2.723	2.754	2.786
9	2.818	2.851	2.884	2.917	2.951	2.985	3.020	3.055	3.090	3.126
10	3.162	3.199	3.236	3.273	3.311	3.350	3.388	3.428	3.467	3.508
11	3.548	3.589	3.631	3.673	3.715	3.758	3.802	3.846	3.890	3.936
12	3.981	4.027	4.074	4.121	4.169	4.217	4.266	4.315	4.365	4.416
13	4.467	4.519	4.571	4.624	4.677	4.732	4.786	4.842	4.898	4.955
14	5.012	5.070	5.129	5.188	5.248	5.309	5.370	5.433	5.495	5.559
15	5.623	5.689	5.754	5.821	5.888	5.957	6.026	6.095	6.166	6.237
16	6.310	6.383	6.457	6.531	6.607	6.683	6.761	6.839	6.918	6.998
17	7.079	7.161	7.244	7.328	7.413	7.499	7.586	7.674	7.762	7.852
18	7.943	8.035	8.128	8.222	8.318	8.414	8.511	8.610	8.710	8.810
19	8.913	9.016	9.120	9.226	9.333	9.441	9.550	9.661	9.772	9.886

Appendix C

A Guide to Plug-in Unit Design for other Frequency Ranges.
When frequency ranges different from those covered by the standard plug-in units are wanted the customer may order a plug-in unit ZS 0122 which contains a suitable printed circuit board without components. The following description may then be used for calculating the necessary components for making up a plug-in unit covering the desired frequency range.

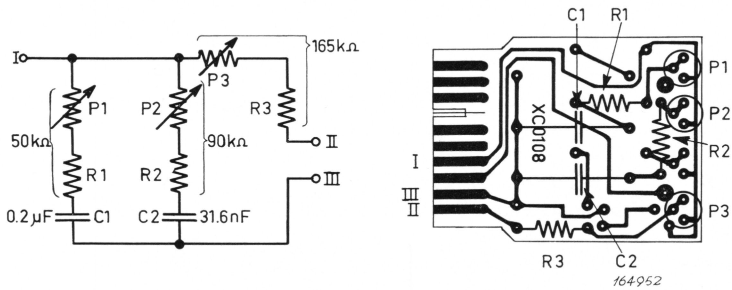


Fig. Ac1. Circuit diagram and layout for a decade filter unit, (20–200 Hz).

An x-deflection filter for the range 20–200 Hz is sketched in Fig. Ac1. For other one decade filters the two capacitors may be calculated from the following:

Frequency range $f_1 - f_2$ ($f_2 = 10\,f_1$)
Scale factor $f_1/20 = f_2/200$
The o.2 μF capacitor is changed to

$$0.2/\text{scale factor} = \frac{0.2 \times 20}{f_1} = \frac{4}{f_1}\,\mu F$$

The 31.6 nF capacitor is changed to

$$31.6/\text{scale factor} = \frac{31.6 \times 20}{f_1} = \frac{632}{f_1}\,nF$$

The resistors will be practically unchanged.

Any frequency range down to one decade may be calculated from the standard filter components in ZS 0120, ZS 0121 and the one decade filter described above. These filters may be converted to other ranges simply by changing all the capacitors by the factor of change in question. No change in relative frequency range will take place.

If at the same time a special relative range is wanted, the known filter closest to the one in question and having a larger frequency range is chosen as a base for the design. If the logarithmic mid-frequency is not changed and a new, smaller relative range is wanted all impedances, including the $1/\omega c$'s, must be multiplied by the factor of range reduction.

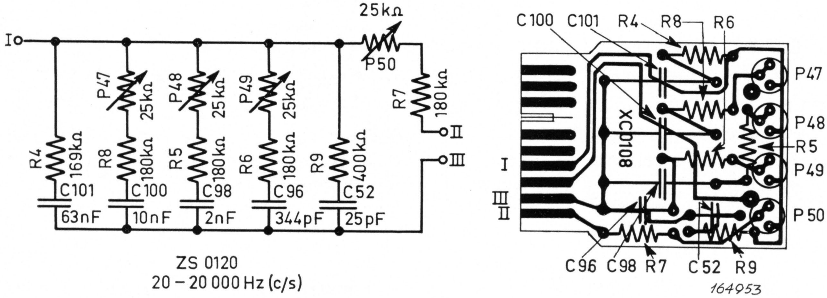


Fig. Ac2. Circuit diagram and layout for the standard plug-in filter ZS 0120. (20–20ooo Hz).

Example:

A range of 100–10ooo Hz is wanted. A ZS 0120 (20–20ooo Hz) is used as a base.

Logarithmic midpoint of ZS 0120 is $\sqrt{20 \times 20ooo} = 630$ Hz.

Logarithmic midpoint of new range is $\sqrt{100 \times 10ooo} = 1ooo$ Hz.

Thus the scale factor for the capacitors will be $\frac{630}{1ooo} = o.63$.

The logarithmic range of ZS 0120 is $\log \frac{20ooo}{20} = 3$.

The logarithmic range of the new filter is $\log \frac{10ooo}{100} = 2$.

Scale factor for all impedances is 2/3.

Factor for resistors is 2/3.

Factor for capacitors is $o.63 \times 3/2 = o.945$, where the factor o.63 is responsible for moving the whole frequency range and the factor 2/3 decreases the range. The factor for the capacitors is close to 1, and we shall see what the results will be if the capacitors are left unchanged:

Frequency range $100 \times o.945$ to $10ooo \times o.945 = 94.5$ to 9450 Hz. As we know that this type of filter is capable of covering one half decade more at both ends of the range than is used in this case, we leave the capacitors unchanged and displace the range by a factor 1/o.945 just by decreasing the resistance between contacts I and II. See Fig. Ac2.

Finally the component values of the new filter will be:

R_4 169 kΩ changed to $169 \times 2/3 = 112$ kΩ

R_8 180 + 12.5 kΩ changed to $192.5 \times 2/3 = 128$ kΩ

R_5 180 + 12.5 kΩ changed to 192.5 × 2/3 = 128 kΩ
R_6 180 + 12.5 kΩ changed to 192.5 × 2/3 = 128 kΩ
R_9 400 kΩ changed to 400 × 2/3 = 267 kΩ
R_7 180 + 12.5 kΩ changed to 192.5 × 2/3 = 128 kΩ

Half the series potentiometer values must be subtracted from the values for R_5, R_6, R_7 and R_8 so that these values will be:

$$R_5 = R_6 = R_7 = R_8 = 128 - 12.5 = 115.5\ k\Omega$$

To obtain the same stability as that of the standard filters supplied, metal film resistors and polystyrene capacitors should be employed.
Ranges extending higher than 20ooo Hz and lower than 5 Hz are not recommended.

Frequency Adjustment of Plug-in Units.

An example is given here for frequency adjustment of the plug-in unit ZS 0120, 20–20ooo Hz range.
Imagine that the potentiometers are numbered 1, 2, 3, 4 from left to right as seen from the front. Adjust as follows:

20 Hz input, potentiometer 1.
500 Hz input, potentiometer 4.
5ooo Hz input, potentiometer 3.
20ooo Hz input, potentiometer 2.

Start from the lowest and finish at the highest frequency in the order indicated. Because of some interaction effects between the adjustments, the procedure must be repeated.
NOTE. The Potentiometer to the extreme left is used for range displacement (zero point) and has no effect on the scale width. *This is normally the only adjustment ever necessary for the standard plug-in units delivered with the Tracer.*

Frequency Scale Multiplication.

If a frequency divider or multiplier is connected between the signal and the EXT. FREQ. INPUT, the frequency scale is still applicable, just being multiplied by a factor equal to the divider. In this way it is possible to use a signal of one frequency (the measurement frequency) for the Y-amplifier while the actual input frequency to the X-amplifier is converted into a frequency suitable for the purpose and bearing a fixed relationship to the measurement frequency. For instance a simple "by two" divider consisting only of a single bistable stage, will convert the frequency scales of 4712 to 400–10ooo and 40–40ooo Hz respectively. As the SIGNAL INPUT should receive the signal directly, the Y-amplifier actually determines the highest signal frequency that can be measured. This amplifier falls off approximately o.5 dB at 200 kHz.

Frequency dividers are available as "building blocks" from many manufacturers. The only requirement is that the output signal should be symmetrical, i.e. positive and negative half periods of the same duration.

Specifications

Input Impedance:	Approximately 100 kohm.
Vertical Deflection:	Arithmetic average signal rectifier calibrated for correct RMS indication of sinusoidal signals. Logarithmic scales 0–50 dB re 10 mV, 0–25 dB re 10 mV and 0–5 dB re 100 mV. Linear scale 0–1 V, linear from o.1 V.
Frequency Response of Vertical Deflection:	Input Potentiometer at maximum. All ranges: within o.5 dB from 5 Hz to 200 kHz, and within o.1 dB from 20 Hz to 50 kHz.
Vertical Speed:	Chosen by switch. Approximately 1 dB ripple at 20 Hz with rise time 60 msec, or 1 dB ripple at 200 Hz with rise time 6 msec.
Horizontal Deflection:	Frequency sensitive, insensitive to signal amplitude.
Frequency Range:	plug-in units delivered as standard accessories: Logarithmic 20–20ooo Hz. Type ZS 0120 and logarithmic 200–5ooo Hz Type ZS 0121. Other ranges may be obtained down to one decade, depending on components in plug-in filter unit.
Frequency Input:	Internal from vertical signal amplifier (min. 5 mV amplifier input) or direct from external generator (o.1–120 V, input impedance 5 kohm). Insertion of a plug into the EXT. FREQUENCY INPUT socket activates a switch disconneting the vertical amplifier input to the frequency sensitive circuit.
Horizontal Speed:	Maximum speed at which spot will follow sudden frequency change is approximately 30 mm per period of signal frequency, i.e. in practice no delay in frequency indication.
Cathode Ray Tube:	14" screen, long persistence.

Rectilinearity:	Pure horizontal or vertical deflection follows the calibration lines on the scale with a deviation of less than ±1 mm.
Scale Accuracies:	Better than 1 % of full scale.
Drift:	Less than 1 mm over one day after 5 minutes warming-up time.
Frequency Sweep:	By motor in BFO, controlled from 4712. Single sweep or continuous.
Sweep Range:	Horizontal deflection reverses the sweep at positions chosen by screwdriver operated potentiometers in 4712.
Stability of Sweep Limits:	Better than 1.5 mm during a day after normal warming-up time.
Sweep Return Mode:	Fast or normal, clockwise or counterclockwise chosen by screwdriver operated switch.
Sweep Return Trace:	"On" or "Off" chosen by screwdriver operated switch.
Blanking:	Below a certain level set by screwdriver operated potentiometer. Maximum blanking level at least half scale.
Power Supply:	100 – 115 – 127 – 150 – 220 or 240 V AC, 50–60 Hz. Consumption approx. 75 Watt.
Mains Voltage Variations:	Mains voltage variations of ± 10 % will cause less than 1 mm spot movement.

Dimensions (excl. knobs):	Height	Width	Depth	Weight
	48 cm	38 cm	35.5 cm	55 lbs.
	19″	15″	14″	25 kg

Cabinet:	The Tracer is delivered in a metal cabinet as a Type A or with a frame for 19″ rack mounting as a Type C instrument.

Accessories:

The following accessories are delivered with the instrument: Power cord, instruction manual, 2 input plugs, 5 blank scales SA 0512, scale SA 0510 20–20ooo Hz, scale SA 0509 200–5ooo Hz, motor drive, plug-in unit ZS 0120 20–20ooo Hz, plug-in unit ZS 0121 200–5ooo Hz, spare fuses and scale lamps.
The following extra accessories may be ordered:
Empty Plug-in Unit ZS 0122.
Plug-in Unit ZS 0124 linear 150–4150 Hz, corresponding scale SA 0511 with 20 linear horizontal and vertical divisions.