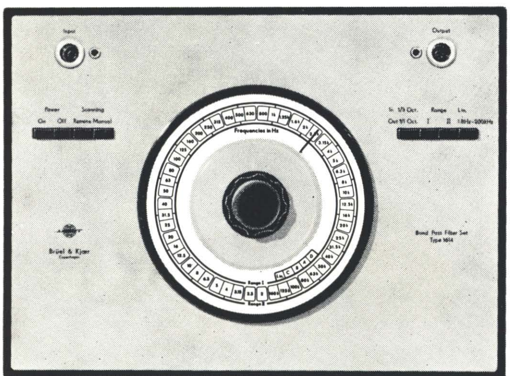
1614, 1615

Instructions and Applications



Octave and 1/3 Octave Filter Sets 1614 and 1615

The Filter Sets are compact instruments of plug-in unit construction. Types 1614 and 1615 filters conform to the IEC 225 and ANSI SI. II. standards and cover the 2 Hz–160 kHz and 25 Hz–20 kHz ranges respectively. "A", "B", "C", "D" and "Linear" networks are also included. Both the filters and the networks can be automatically scanned.

BRÜEL & KJÆR

030-0087

Octave and 1/3 Octave Filter Sets

Types 1614 and 1615

Reprint may 1970

CONTENTS

1. INTRODUCTION

The Filter Sets Types 1614 and 1615 are a development of the older design (Type 1612). The filter performance is generally improved and the Type 1614 includes extra filters at both low and high frequencies. Both 1614 and 1615 contain the sound weighting networks A, B, C, and the more recently introduced D network.

The Filter Sets are primarily designed for vibration and acoustic frequency analysis, and have specifications and tolerances which conform to the following standards:

IEC 225 1966
ANSI S1.11-1966 (1/3 octave Class III, 1/1 octave Class II)
DIN 45652

The filters are band-pass filters, with 1/3 octave bandwidths. The filter centre frequencies are spaced 1/3 octave apart, and filter selection is by a 50 - position switch on the front panel. In the octave mode, 3 adjacent 1/3 octave filters are connected such as to produce a 1/1 octave bandwidth. Filter selection is either manual or by remote control, enabling synchronization with other equipment.

Linear ranges and the A, B, C, and D networks are also selected by the 50 - position switch.

The input and output to the filters can be connected to a wide range of terminating impedances. For Field measurements provision is made for 12 V DC operation.

Frequency analysis over a very wide frequency range can be accomplished with the Filter Set in conjunction with a B & K Sound and Vibration Measuring amplifier Type 2606 or Type 2603 or the B & K Sound Level Meters. 1/3 octave or 1/1 octave bands of random noise may also be produced by using the Filter Set in conjunction with the B & K Random Noise Generator Type 1402. These and other typical uses of the Filter Set are briefly mentioned in Chapter 4 of this Manual.

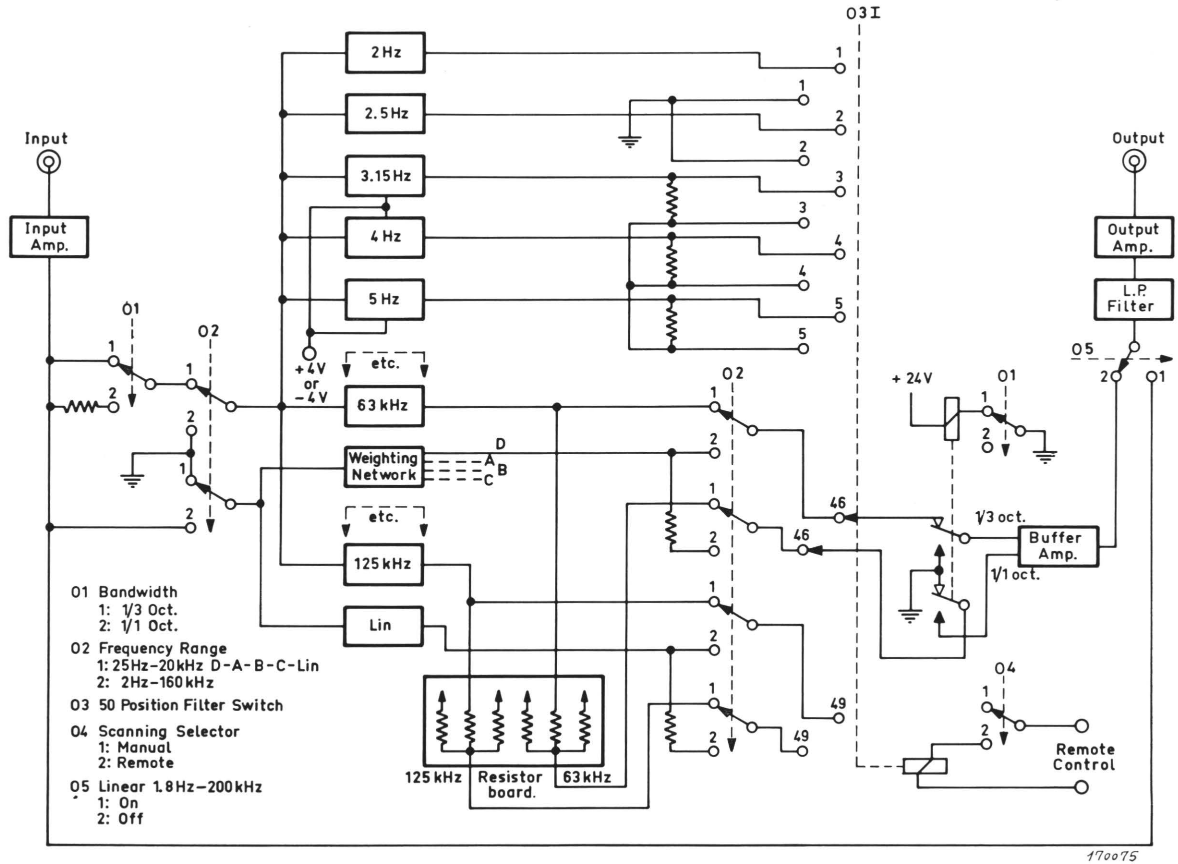


Fig.2.1. Block Diagram

2. TECHNICAL DESCRIPTION

The block diagram in Fig.2.1 shows the basic design of the instrument. The signal is fed via an input amplifier to the filter inputs, which are connected in parallel. The input amplifier has a high input impedance, and drives the filters from a low output impedance. The filter outputs are selected by the 50 - position switch. When in the octave mode, the outputs of three adjacent 1/3 octave filters are connected together (via resistors). The signal from the filters is fed to two inputs of a buffer amplifier.
A subsidiary range of filters, from 25 Hz to 20 kHz with D, A, B, C and Linear filters can also be selected. This is also the only frequency range of the 1615, which does not possess the low and high frequency filters.
The 50 position switch can be operated by actuating the electromagnetic drive unit from the remote control socket.
The Filter set can be operated from normal mains supplies or from a 12 V DC accumulator, for which purpose there is a DC - AC converter.

INPUT AMPLIFIER

The input amplifier provides the low impedance ($\sim 0.8\,\Omega$) drive required for the filters. It has an input resistance of 125 $K\Omega$ in parallel with 55 pF, and a gain of 0 dB. Its frequency response is flat from 1.8 Hz - 200 kHz within ± 0.1 dB.

1/3 OCTAVE FILTERS

The 1/3 octave filters are all 6-pole Butterworth networks and have the centre frequencies and bandwidths given in Table 1.
The 2 — 200 Hz filters are active circuits consisting of 3 stagger tuned Wien-bridge amplifiers, with an emitter follower output to reduce the output impedance.
The other 1/3 octave filters are passive networks. Schematic diagrams for both active and passive 1/3 octave filters are shown in Fig.2.2 and 2.3

Centre Frequency Hz	Bandwidth Hz	Centre Frequency Hz	Bandwidth Hz
2	0.46	630	145
2.5	0.58	800	183
3.15	0.73	**1000**	230
4	0.92	1250	290
5	1.16	1600	370
6.3	1.45	**2000**	460
8	1.83	2500	580
10	2.30	3150	730
12.5	2.90	**4000**	920
16	3.70	5000	1160
20	4.60	6300	1450
25	5.8	**8000**	1830
31.5	7.3	10000	2300
40	9.2	12500	2900
50	11.6	**16000**	3700
63	14.5	20000	4600
80	18.3	25000	5800
100	23	**31500**	7300
125	29	40000	9200
160	37	50000	11600
200	46	**63000**	14500
250	58	80000	18300
315	73	100.000	23000
400	92	**125.000**	29000
500	116	160.000	37000

Table I. Filter centre frequencies and bandwidths.

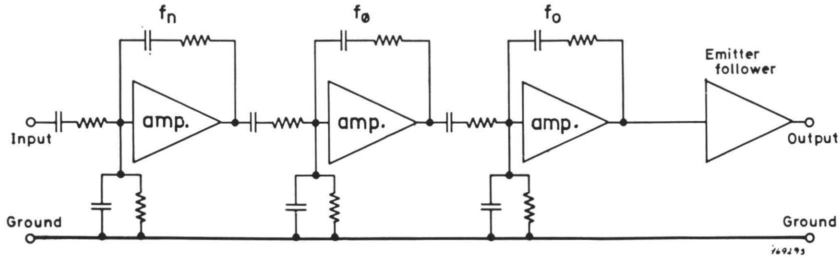


Fig. 2.2 Schematic diagram of a single 1/3 octave active filter network

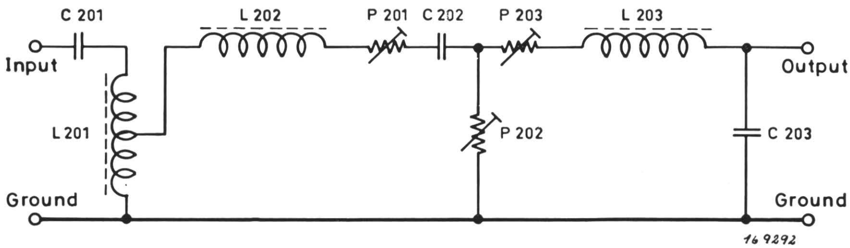


Fig.2.3 Schematic diagram of a single 1/3 octave passive filter network

The overall characteristics conform to the existing standards for 1/3 octave filters. Typical examples of filter characteristics are shown in Fig.2.4, 2.5.
Peak-valley ripple in the pass band is less than 0.5 dB and rejection is greater than 75 dB at frequencies of five times and one fifth of the centre frequency.
A typical set of adjacent filter characteristics is shown in Fig.2.6 The frequency characteristics cannot be expected to intersect exactly at the 3.7 dB point because of the steep slope at this point. A very small displacement of the filter centre frequency will cause a large displacement of the point of intersection.
A buffer amplifier is placed directly after the 1/3 octave filters. This is necessary because the filter characteristics are very dependent on the terminating impedance.

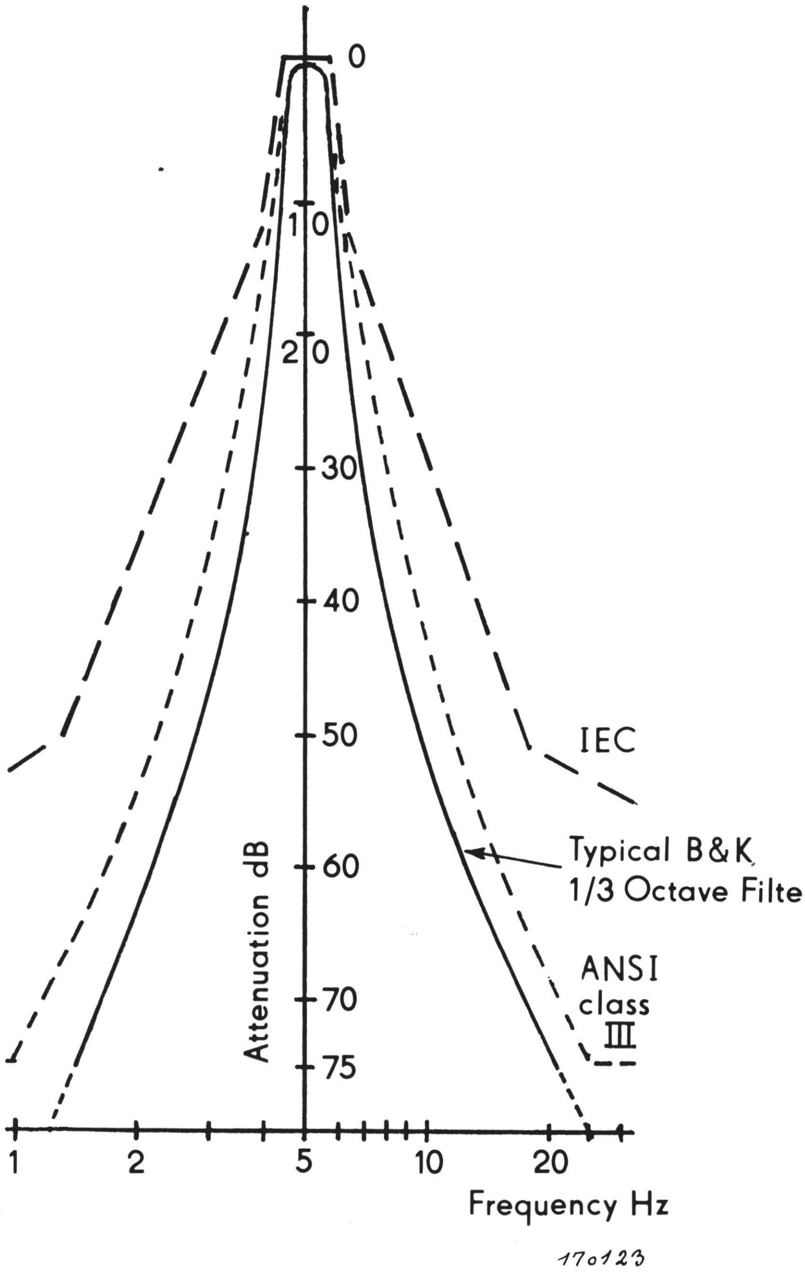


Fig.2.4 Typical 1/3 octave filter frequency response and tolerances

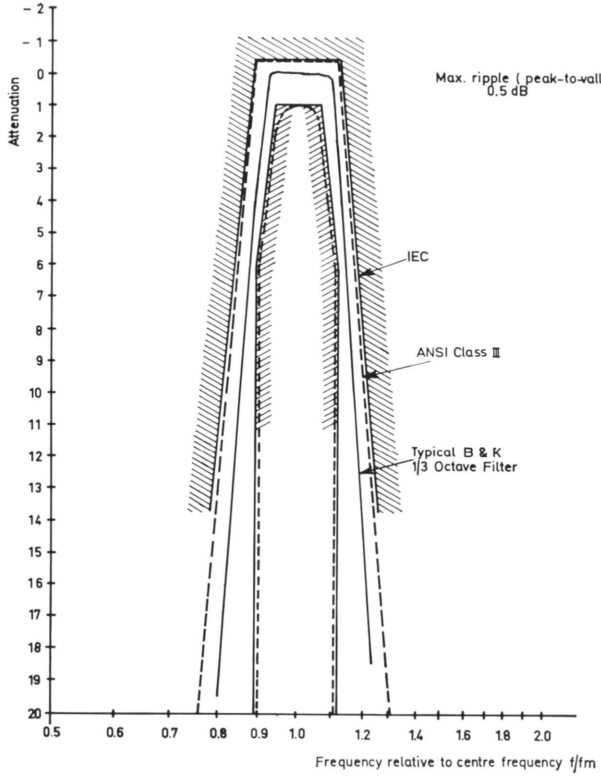


Fig. 2.5 Top of typical 1/3 octave frequency response and tolerances

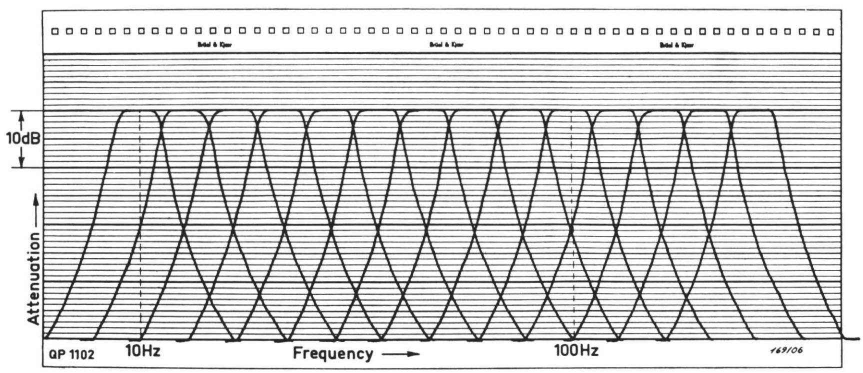


Fig. 2.6 Frequency response of several adjacent 1/3 octave filter

OCTAVE FILTERS

The octave filters are formed from three adjacent 1/3 octave filters, connected in parallel with resistors in series with other. Octave filter centre frequencies are given in bold type in Table I.

Typical octave filter response is shown in Fig.2.7. All filter responses are measured with single frequency sinusoidal voltages.

The peak-valley in the pass band is better than + 0.5, – 1.0 dB, and the rejection outside the passband is greater than 60 dB at eight times and one-eighth of the centre frequency.

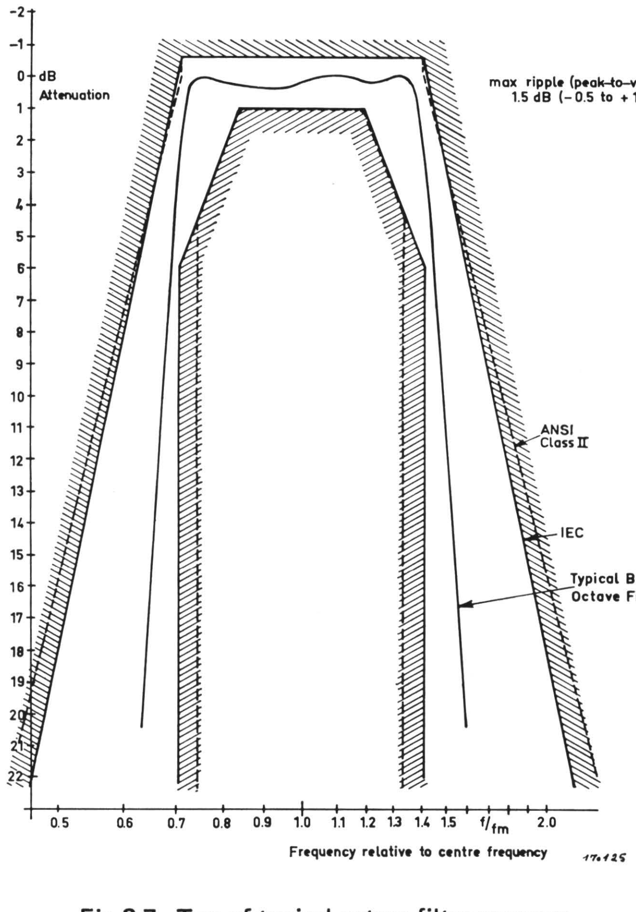


Fig. 2.7 Top of typical octave filter response

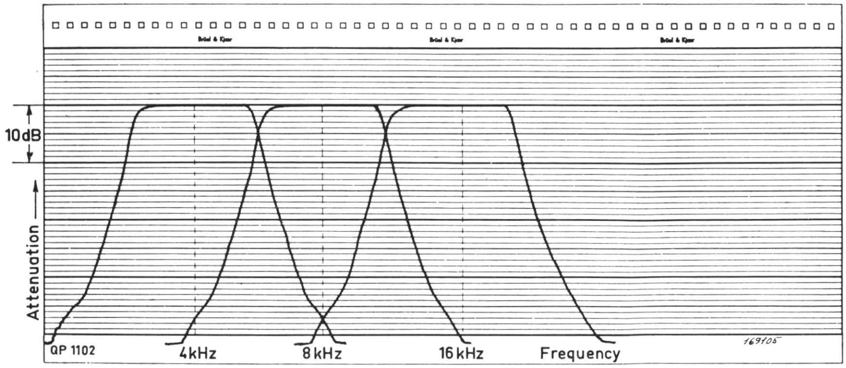


Fig.2.8 Frequency response of several adjacent 1/1 octave filters

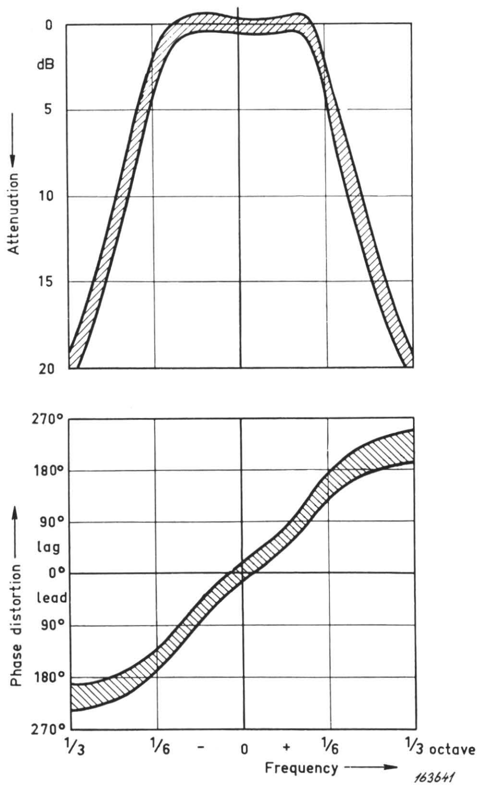


Fig.2.9 Phase response of Filter Set in 1/3 octave condition

EFFECTIVE BANDWIDTH

Table I gives the bandwidth at the –3.7 dB points. This bandwidth is 1/3 octave and is also the effective bandwidth of the filter. See "Definitions".

When filtering white noise, the RMS noise voltage from the filter can be in error ± 0.4 dB when using the effective bandwidth of 1/3 octave, because of the production tolerances on the filters.

PHASE RESPONSE

The filters, by their nature, produce considerable phase distortion in the pass band. Figs. 2.9, 2.10, show the limits within which the different filter curves for the whole apparatus are expected to lie.

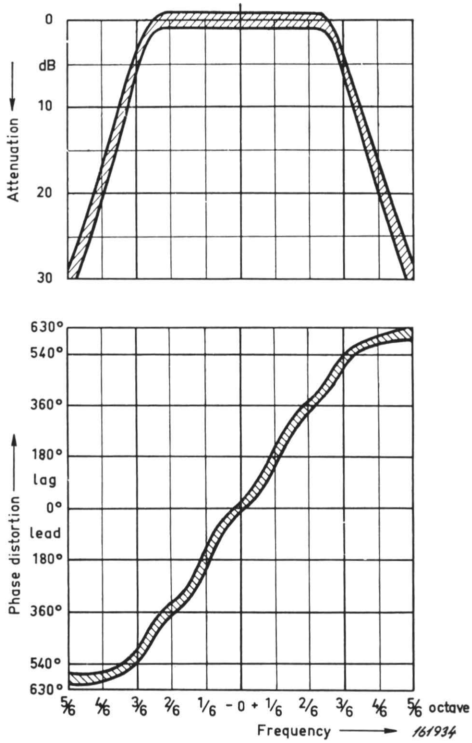


Fig. 2.10 Phase response of Filter Set in 1/1 octave condition

FILTER TRANSIENT RESPONSE

The filter inputs are all connected to the input terminal in parallel so that during an analysis when the filter set is being scanned, there are no filter transients. The transient response of filters is actually quite complex, depending on the input waveform as well as the type of filter, but normally need not be taken into account for measurements with the 1614/15.
However, the response of the filters to a suddenly applied sinusoidal signal has been determined, and is shown in Fig.2.11.
The filter output normally requires about 15 periods to stabilize to the steady state. This means about 8 secs. for the 2 Hz filter, so this could become a difficulty when making low frequency measurements. If scanning starts at 2 Hz and is too fast, and the input signal is started at the same time as scanning, then the filter output will not have reached the steady state. 8 sec. would be required in the 2 Hz filter, from the time of switching on.

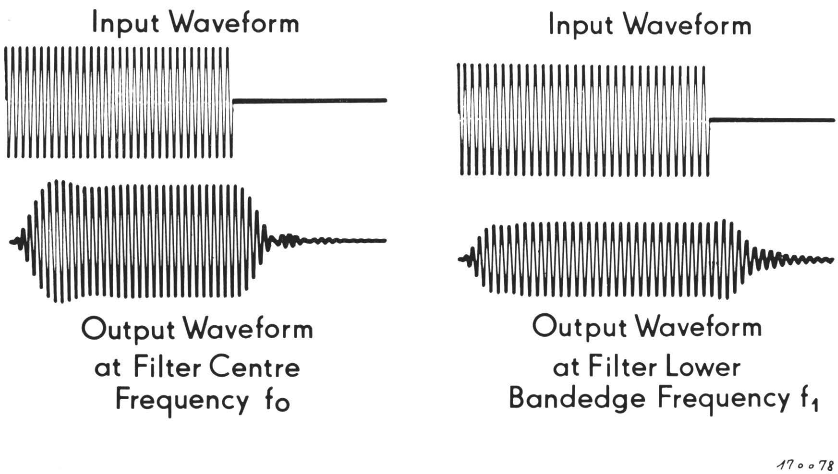


Fig.2.11 Filter transient response to sinusoidal burst (shown in correct time relationship to input signal

WEIGHTING NETWORKS

The A, B and C weighting networks are internationally standardized (IEC 179 for precision sound level meters) and their use is well-known in sound measurement. The D network was more recently introduced, and complies to the DIN standard and to the proposed IEC standard. The frequency responses of these filters are shown in Fig.2.12. They are selected by the 50 position switch when the Frequency Range selector is in position I.

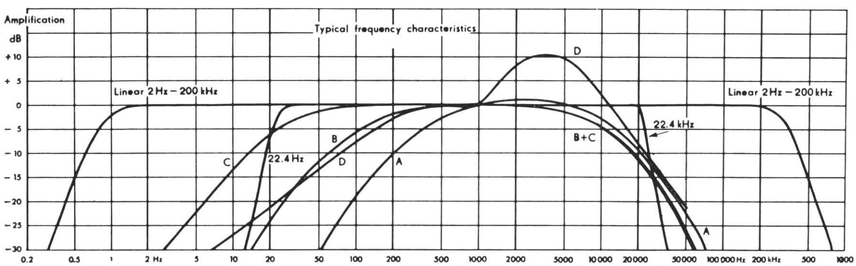


Fig.2.12 Frequency response of A, B, C, D and linear Scales

LINEAR RANGES

The linear ranges are 22.4 Hz to 22.4 kHz on the 50 position switch, and 1.8 Hz to 200 kHz on the pushbutton switch.
See specifications for further details.

OUTPUT AMPLIFIER

The output amplifier compensates for an attenuation in the 200 kHz LP filter of about 6 dB and presents the correct output impedance to the output sockets (i.e. 600 Ω).

REMOTE CONTROL

The Filter Switch can be manually or automatically operated, the latter being achieved by a remotely controlled electromagnetic drive unit. To obtain remote control an external DC supply (24 V, 180 mA) in series with a single-poled switch is required. The connections to be made to the jack REMOTE CONTROL can be seen in Fig.2.13.

NOTE: Take care that the + terminal of the external DC source is connected with pin 2 and the −terminal with pin 1. If inversely connected a spark-suppressor diode will be damaged.

When the switching action is controlled from the Level Recorder Type 2305 a special cable AQ 0019 has to be applied between the two instruments.

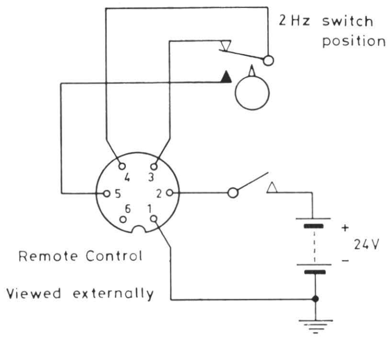


Fig.2.13 Connections to socket REMOTE CONTROL for remote control of Filter Switch.

3. CONTROLS

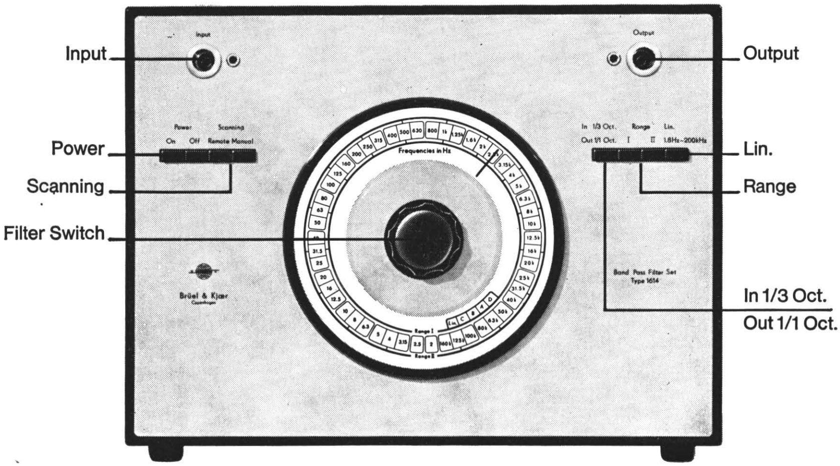


Fig.3.1 Front Panel

CONTROLS AND TERMINALS, FRONT PANEL

POWER	Push-button on-off switches.
SCANNING	With the Manual button depressed the Filter switch may be turned freely to any position. When the Remote button is depressed the electromagnetic drive unit is switched in and the filter switch can be operated from the Remote control socket on the rear panel.

1/1 OCTAVE 1/3 OCTAVE SELECTOR	With this button depressed the filter set is in the 1/3 octave mode, and with this button out, in the 1/1 octave mode. When the filter is set in the 1/1 octave mode, there will be three adjacent positions on the dial for each 1/1 octave filter. The centre frequency of the selected 1/1 octave filter is indicated in the centre position.
FREQUENCY RANGE SELECTOR	The two frequency ranges I and II are 25 Hz - 20 kHz, D, A, B, C and Linear, and 2 Hz - 160 kHz respectively. The Type 1614 contains both ranges, but the Type 1615 contains only the filters in range I. On the dial of the 1614, the two ranges are distinguished by the bold circles. When the 50—position switch is placed outside the frequency range of the 1615 there will be no output from the filter set. Also no output will appear in the 1614 at the same positions of the filter switch, whilst frequency range I is selected.
LINEAR RANGE	With the Lin. 1.8 Hz - 200 kHz button depressed the Filter Set has a flat response. (±0.1 dB) from 1.8 Hz—180 kHz and ± 0 dB to —0.5 dB from 180 kHz to 200 kHz.
FILTER SWITCH	The central knob can be rotated in either direction (in Manual Scanning position) for selection of the individual filters. This knob has 50 positions in all.
INPUT AND OUTPUT	The input and output sockets are the standard B & K coaxial type, fitting plug JP 0101 etc.

CONTROLS AND TERMINALS, REAR PANEL

INPUT AND OUTPUT	These sockets are identical to the input and output sockets on the front panel
REMOTE CONTROL	6 pin plug for remote control of filter switching. See TECHNICAL DESCRIPTION.

POWER INPUT, AC	The normal mains input (AC) is connected by means of the cable supplied. The transformer tapping should be adjusted to suit the power line voltage by means of the selector around the AC fuse.
POWER INPUT, DC	A 12 V DC supply can be connected (to the two bottom pins) to the 12 V DC power socket. The 12 V supply must deliver 1.5 A. An accumulator is suitable for this purpose.
AC–DC SWITCH	This switch should be up for AC, down for DC operation.
FUSES	There are separate fuses for AC and DC supplies.

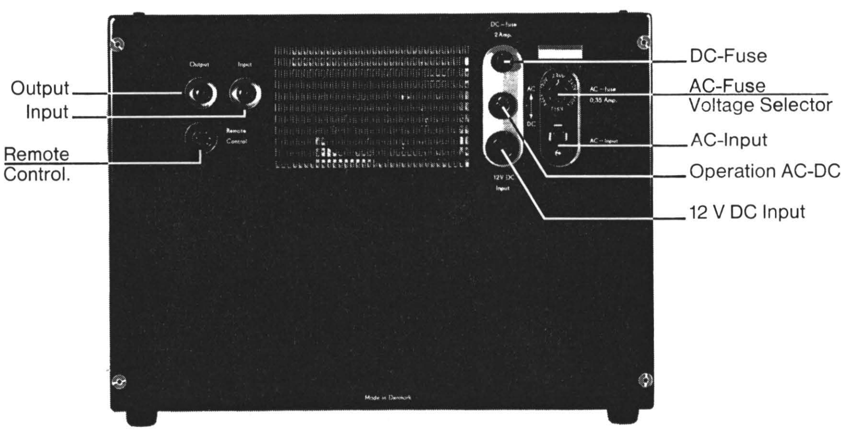


Fig.3.2 Rear Panel.

4. OPERATION

GENERAL

The Bandpass Filter Sets Types 1614/15 are used for analysis of waveforms in 1/3 and 1/1 octave bands. If the filter output is to be measured, amplified or attenuated, or if the input signal is greater than 1 V RMS, suitable instrumentation needs to be used in conjunction with the 1614/15, B & K Amplifier Types 2603, 2604 and 2606 perform the above functions as does Frequency Analyzer Type 2107. The 1614/15 can also be used with the Portable Precision Sound Level Meter Type 2203 and Impulse Precision Sound Level Meter Type 2204 for waveform analysis. By using the Level Recorder Type 2305 the filters can be automatically scanned in succession and the resulting analysis can be recorded. Using the 1614 in conjunction with the FM Tape Recorder Type 7001 frequencies down to 0.05 Hz can be analyzed using frequency transformation techniques provided suitable low frequency measuring equipment is available. Another possible use of the 1614/15 is the production of 1/3 and 1/1 octave bands of noise when used with random noise Generator Type 1402. Operation of the 1614/15 with the above mentioned instrumentation follows latter in this chapter.

1. CONVERSION OF TYPE 1615 TO 1614

The Type 1615 Filter Set does not contain the 1/3 octave filters 2 Hz to 20 Hz and 25 kHz to 160 kHz.

These filters can be obtained from B&K, it is a simple matter to insert them and no adjustments are necessary, B&K numbers for these filters are given below under "Active and passive 1/3 octave filters". It should be pointed out that a Resistor Board, B&K no. XZ 0013 is also required when 50–160 kHz filters are to be used and a new front panel scale, SA 0133, should be mounted.

Firstly, remove the instrument case after unscrewing the four screws on the rear panel. Next, remove the metal panel on which the filter positions are indicated.

The extra filters are inserted into the indicated positions after removing the dummy cards, taking care that they slide properly into the slots. (The filter cards are secured only by the slots).

Active 1/3 octave filters for 1614

Filter Centre Frequency f_o Hz	Filter Stock no	Filter Centre Frequency f_o Hz	Filter Stock no
2	ZT 0001	25	ZT 0012
2.5	ZT 0002	31.5	ZT 0013
3.15	ZT 0003	40	ZT 0014
4	ZT 0004	50	ZT 0015
5	ZT 0005	63	ZT 0016
6.3	ZT 0006	80	ZT 0017
8	ZT 0007	100	ZT 0018
10	ZT 0008	125	ZT 0019
12.5	ZT 0009	160	ZT 0020
16	ZT 0010	200	ZT 0021
20	ZT 0011		

Passive 1/3 octave filter for 1614

Filter Centre Frequency f_o Hz	Filter Stock no	Filter Centre Frequency f_o Hz	Filter Stock no
250 315	ZS 0154	4K 5K	ZS 0160
400 500	ZS 0155	6.3K 8K	ZS 0161
630 800	ZS 0156	10K 12.5K 16K 20K	ZS 0162
1K 1.25K	ZS 0157	25K 31.5K 40K	ZS 0163
1.6K 2K	ZS 0158	50K 63K 80K	ZS 0164
2.5K 3.15K	ZS 0159	100K 125K 160K	ZS 0165

After the extra filters have been inserted, the front panel scale should be changed. This is done after removing first the filter switch knob by means of an Allen Key, then the plastic cover which is secured by 4 plastic pegs held by spring clips, and last the filter switch pointer. The scale is held by two screws. After changing the scale and replacing the pointer, the pointer position should be checked in the following way:

The top two pins no. 3 and 4 of the remote control socket should show an open circuit in all except one position of the filter switch. This position is when the 2 Hz filter is selected. Hence an ohmmeter or lamp and battery connected to these two pins will enable the switch pointer position to be set correctly.

The plastic cover should be replaced carefully to avoid breaking the pins.

2. USE WITH MICROPHONE AMPLIFIER TYPES 2603/04

These Amplifiers have similar specifications differing only in frequency response.

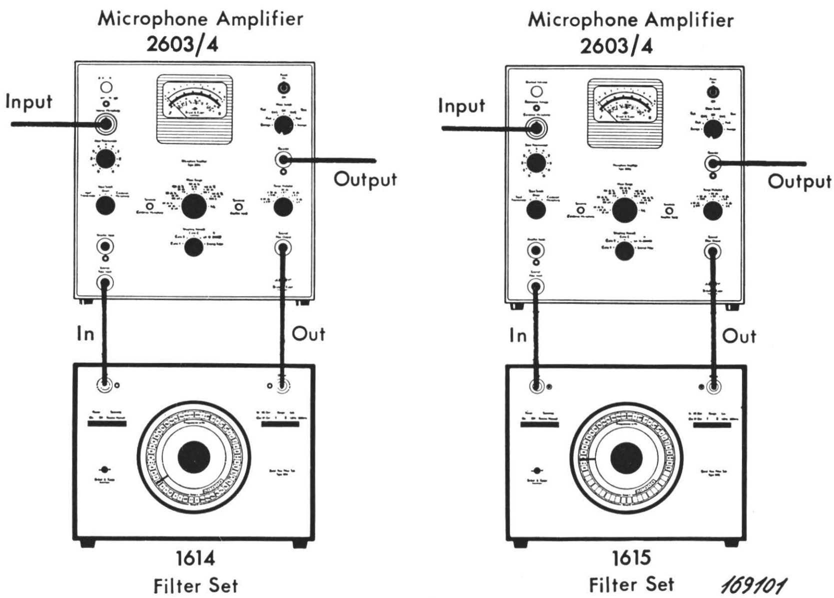


Fig.4.1 Filter Set Type 1614/15 combined with Microphone Amplifier Types 2603/04

The frequency range of the 2603 is:

"Linear"	2 Hz – 40 kHz ±0.5 dB relative to 1000 Hz
	5 Hz – 20 kHz ±0.3 dB relative to 1000 Hz

and of the 2604:

"Linear"	10 Hz – 200 kHz ±0.5 dB relative to 1000 Hz
	20 Hz – 100 kHz ±0.3 dB relative to 1000 Hz

As seen the 2603 covers range I, and up to 40 kHz of range II of the 1614 and the complete range of the 1615. The 2604 covers range I of the 1614 and the complete range of the 1615, but not under 10 Hz in Range II of the 1614.
A typical measuring set-up of the 1614/15 and 2603/04 is shown in Fig. 4.1. The system can be used for sound and vibration analysis or for analysing voltage waveforms.

MEASURING ARRANGEMENT

1. Set up the Microphone Amplifier on the desired measuring arrangement.
2. Wire up Band-Pass Filter Set and Microphone Amplifier according to Fig. 4.1.
3. Set FREQUENCY RESPONSE SWITCH respective WEIGHTING NETWORK of Microphone Amplifier to "External Filter".
4. Set control knobs on Band-Pass Filter Set.

   POWER "On"
   SCANNING "Manual"

   Choose 1/3 or 1/1 octave bands as desired.

   FILTER SWITCH to the filter at which the measurement should be carried out.
5. Apply the signal to be analysed to the arrangement.
6. Turn METER RANGE from the "Ref" position counterclockwise until the overload Indicator just shows overload. From this position turn one step clockwise. Indicator should now show no overload.
7. Set METER SWITCH to "R.M.S.", "Average" or "Peak". "Fast" or "Slow" as desired.
8. Set RANGE MULTIPLIER to obtain suitable indicating meter deflection, preferable between 10 and 20 dB on scale.

The signal level within the chosen filter, and referred to the input of the measuring arrangement is read according to the same method as explained in the instruction manual for the Microphone Amplifier Type 2603/04.

CALIBRATION

Two different calibrations of the system can be used, one calibration with respect to the measuring transducer used, the other, a calibration as a voltage analyser. For calibration with respect to the transducer two methods are available:
One using the transducer sensitivity correction factor the other a direct physical calibration using some suitable acoustical or vibration calibrator. For further information refer to the appropriate B & K Instruction Manual on the transducer employed.

1. Set control knobs of Microphone Amplifier:

INPUT SWITCH:	"Direct"
METER SWITCH:	"Ref."
METER RANGE:	"Fast", "RMS"
RANGE MULTIPLIER:	"x1, 0dB"
FREQUENCY RESPONSE SWITCH respective WEIGHTING NETWORK:	"External filter"

2. Set control knobs of Filter Set:

POWER	"On"
SCANNING	"Manual"

3. The meter should now show a deflection to the red mark on the microphone scale. Possible deviations being corrected by the screwdriver operated potentiometer marked SENSITIVITY - AMPLIFIER INPUT on the front panel of Microphone Amplifier.

As stated the Level Recorder Type 2305 can be used to scan the Pass Band Filter Set and record the subsequent analysis. The synchronization is described in Fig.4.8.

3. USE WITH AMPLIFIER TYPE 2606

The Type 2606 is a more advanced model of the 2603/04 with a wider overall frequency range (2 Hz—200 kHz) which covers both the 1614 and 1615. A typical set up for operation is shown in Fig.4.2. This system can be used to record sound or vibration or analyse other voltage waveforms if desired. It should be born in mind, that the meter time constant of the 2606 does not conform to signals below 8–10 Hz. For low frequency measurements the "Sound and Vibration Measuring Amplifier" Type 2607 should be used.

MEASURING PROCEDURE

1. Connect up instrumentation as in Fig.4.2.

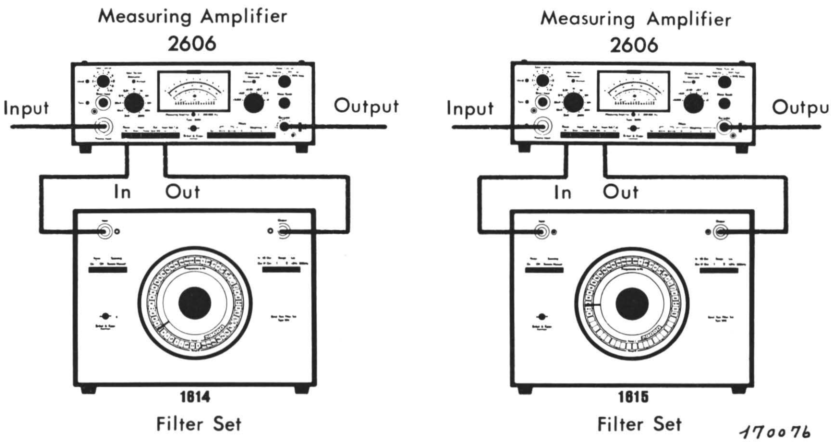


Fig.4.2 Filter Set Type 1614/15 combined with Amplifier Type 2606

2. The 2606's controls should be set as follows

POWER	"On" Turn switch to AC or DC depending on external power supply.
INPUT	Using B & K coaxial plugs "Direct" Using B & K 7 pin plugs "Preamplifier Input"
METER FUNCTION	RMS "Slow" or RMS "Fast"
GAIN CONTROL	"Cal."

Switch in External Filter.

3. If the 1615 or Selective Range I of the 1614 is used the low pass and high pass filters with cut off frequencies of 22.4 Hz and 22.4 kHz can be switched in to limit the frequency range.

4. The 1614/15 controls should be as follows:

POWER	"On"
SCANNING	"Manual"

The 1/3 and 1/1 octave frequency ranges of the 1614 should be switched on as desired.
Filter Switch to the filter at which the measurement is carried out.

5. The INPUT SECTION ATTENUATOR and OUTPUT SECTION ATTENUATOR knobs should be set such that (a) no overload appears on either Input or Output stage.
(b) a suitable indicating meter deflection is obtained, preferably in the upper end of the scale.
The Signal Level within the chosen filter and referred to the input measuring arrangement is read according to the method explained in Instruction Manual 2606.

CALIBRATION

As with the 2603, 2604 calibration of the system can be made either with reference to the measuring transducer or as a voltage analyser. For calibration with respect to the measuring transducer reference should be made to the appropriate Instruction Manual.
For calibration as a voltage analyser follow procedures 1) and 2) as above and select the "ref. 50 mV".
When the 2606 "ref. 50 mV" is switched in, the meter reading should be 50 mV for attenuator settings of 0.1 V and Output Section attenuator of X 1.
If not, suitable adjustment can be made by means of the sensitivity adjustment screws at the Direct or Microphone Inputs.
The Level Recorder Type 2305 can be used with the 2606 and 1614/15 to automatically scan the Pass-Band Filter Set and record the subsequent analysis.

4. USE WITH FREQUENCY ANALYZER TYPE 2107

The 2107 has terminals similar to the 2603/04 for use with the 1614/15. As with the 2603/04 when the switch WEIGHTING NETWORK of the Frequency Analyzer is in External Filter Position and the knob Function Selector is switched to "Selective Section Off" the 2107 is ready for use. Calibration is similar to that for the 2603/04 as is the linear frequency range.
The 2107 is able to analyse between 20 Hz—20 kHz. If a broad band signal is to be analysed in this frequency range a 1/1 or 1/3 octave analysis can be

made using the 1614/15 - and a more accurate analysis can be made using the 2107 in any desired pass band.
The frequency characteristic of the Frequency Analyzer when the switch FUNCTION SELECTOR is in position frequency analyzer can be adjusted by a knob marked FREQUENCY ANALYSIS OCTAVE SELECTIVITY.
The frequency characteristic for maximum selectivity is shown in Fig. 4.3. It can be seen from the figure (curve a) that the attenuation slope just outside the pass-band is very steep. However, further away from the pass-band the attenuation slope is no longer so steep. If, for some reason, it is desired to produce a very narrow passband with very steep attenuation slope also further away from the center frequency, it is possible to combine the attenuation characteristics of the 2107 Analyzer with the 1/3 octave condition of the Band-Pass Filter Set, see also curve b Fig.4.3.

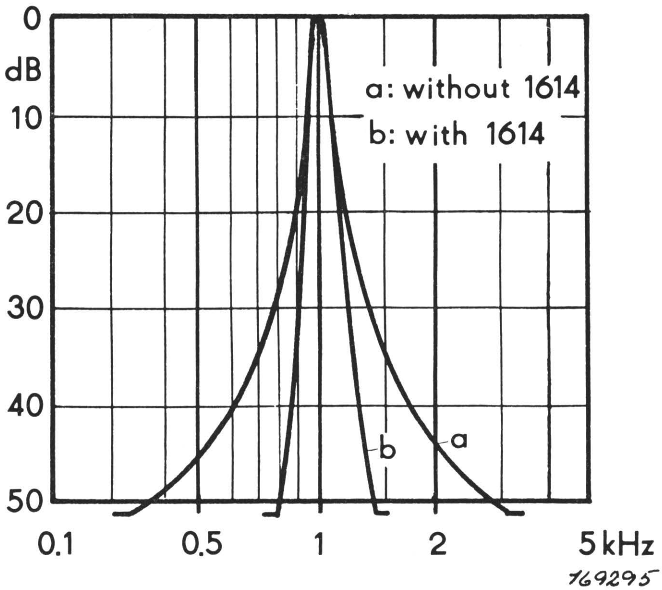
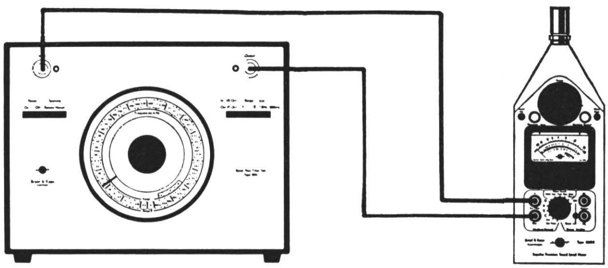


Fig.4.3 Frequency Characteristic of the Frequency Analyzer Type 2107 for maximum selectivity

5. USE WITH PRECISION SOUND LEVEL METER TYPE 2203 AND IMPULSE PRECISION SOUND LEVEL METER TYPE 2204

Using these two portable meters, sound and vibration analysis can be done in the field with the 1614,provided a 12 V DC battery to power the latter is available. The 2203's frequency range is (10 Hz - 25 kHz) suitable for audio frequency analysis with the 1614/15, or vibration analysis in that range. The 2204 adds to the versatility of the 2203 by providing in a model of the same external dimensions as the 2203 the ability to measure impulsive noise accurately. The frequency range for normal sound and vibration measurements is (2 Hz - 70 kHz).
For calibration and operation of the 1614/15 and 2203/04 refer to the Instruction manuals on the B & K measuring transducer employed. A typical measuring set up employing the 1614/15, 2203/04 is shown in Fig. 4.4..



2204
Impulse Precision
Sound Level Meter

1614 or 1615
Filter Set

170077

Fig.4.4 Filter Set Type 1614/15 combined with Precision Sound Level Meters 2203/04

OPERATION

1. Connect Set up as in Fig.4.4
2. To operate 2203. Pull Function knob out and turn to Ext. Filter.
   To operate 2204. Turn meter switch (outer knob) to Fast or Slow, then turn weighting network (inner knob) to Ext. Filter.

3. Set Filter Controls

POWER	"On"
SCANNING	"Manual"

Selective Ranges and 1/1 and 1/3 octave band switched in as desired. FILTER SWITCH to the filter at which the measurements are to be carried out.

4. The two ranges setting switches (upper switches) should be set so that the meter pointer should be in the upper half of the scales and the outer transparent knob should always be as far clockwise as possible to give the best signal to noise ratio.

The signal within the chosen filter and referred to the input of the measuring arrangement is read according to the method described in the Instruction Manual for 2203, 2204. These should also be referred to for checking of the battery supplies.
For calibration of the system with respect to B & K measuring transducer refer to its Instruction Manual.

6. USE WITH F.M. TAPE RECORDER TYPE 7001

The F.M. Tape Recorder Type 7001 has a linear frequency range from DC up to 20 kHz depending on the tape speed employed. Using frequency transformation techniques, the 7001 and 1614 can be used to make very low frequency sound and vibration measurements. The 7001 contains a voice channel to allow for marking and identification of the tapes. A signal from a 440 Hz ref. generator can be recorded on the voice channel. The 440 Hz signal can be used to control the marker unit during playback. This unit can control the switching of the 1614/15 when frequency analysis is made from tape loop and recorded graphically by means of the Level Recorder Type 2305. A synchronisation can be obtained between the movement of the preprinted recording paper and the tape loop cycle. A requirement for such a synchronisation is that the tape loop cycle must be longer than the time required for the recording paper to advance 1/3 octave. Further details can be obtained from the Instruction Manual 7001.

7. USE WITH RANDOM NOISE GENERATOR TYPE 1402

1/3 and 1/1 Octave bands of noise can be supplied from the Noise Generator when the Filter Sets Types 1614/15 are inserted between the microphone amplifier section via the two EXTERNAL FILTER terminals of the Noise Generator. By using this combination of the Noise Generator plus Band-Pass Filter Set the characteristic of the Noise signal fulfils among other

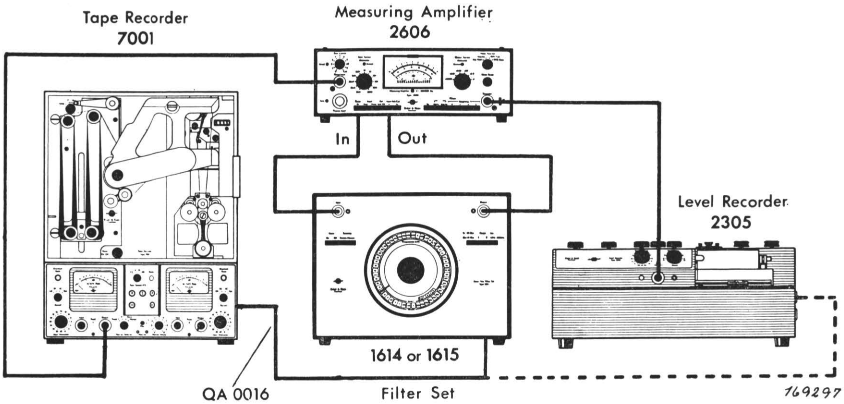


Fig.4.5 Set-up for synchronised frequency analysis of tape recording

things the requirements included in the I.S.O. Recommendation for measurements of Absorption Coefficients in a Reverberation Room and "Field and Laboratory Measurements of Airborne and Impact Sound Transmission". However, the 1402 has too limited a frequency range (20 Hz— 20 kHz ±1 dB) at full output power, to utilize the complete frequency ranges of the 1614/15. The Level Recorder Type 2305 can be used to automatically scan the 1614/15.

OPERATION

A combination of the 1402 and 1614/15

(I) Connect up circuit as shown. Fig.4.6.

(II) Set control knobs on Filter Set as follows:

POWER "On"

SCANNING "Manual"

Selective range 1/3 or 1/1 octave bands as desired.

(III) Set the control knobs on the Noise Generator as follows:

1 METER TIME CONSTANT is set to a position where a stable deflection of the indicating meter pointer is achieved.

NOTE: Using a high meter-time-constant value, the METER TIME CONSTANT may first be set to a low value and then to the position required. In this manner a faster reading is obtained.

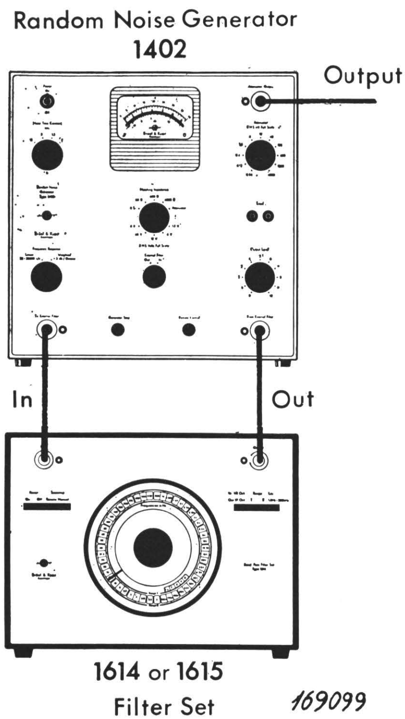


Fig.4.6 Filter Set Type 1614/15 combined with Random Noise Generator Type 1402

2. Set switches

EXTERNAL FILTER	"In"
FREQUENCY RESPONSE	"Weighted −3 dB/octave"

3. Turn OUTPUT LEVEL so that a suitable deflection on the indicating meter is obtained.

4. Two output terminals can be employed:
ATTENUATOR OUTPUT intended for high impedance loads (5 kΩ or higher)
LOAD intended for low impedance loads (6Ω to 6000Ω)

NOTE: The right terminal is grounded.

ATTENUATOR OUTPUT:

Set MATCHING IMPEDANCE in position "Attenuator" and adjust to the appropriate signal level by OUTPUT LEVEL potentiometer and ATTENUATOR.

LOAD:

Set MATCHING IMPEDANCE to a value as near as possible to that of the load impedance, and adjust to appropriate signal level by OUTPUT LEVEL potentiometer.

8. USE WITH LEVEL RECORDER TYPE 2305

When the B & K Level Recorder Type 2305 is used in an integrated measuring system including the Band-Pass Filter Set the filters and weighting networks of the latter can be selected automatically in succession via the Level Recorder. The setting up and adjustment of the Recorder's single chart automatic stop and the synchronization of filter switching and recording paper calibration is as given below:
Interconnect the Recorder 7–pole REMOTE CONTROL socket with the Filter Set's REMOTE CONTROL socket by using the remote control cable (AQ0019) see Fig.4.7.

1. Insert the desired type of frequency calibrated paper and mount pen or sapphire. If necessary, see instruction manual for the Level Recorder.

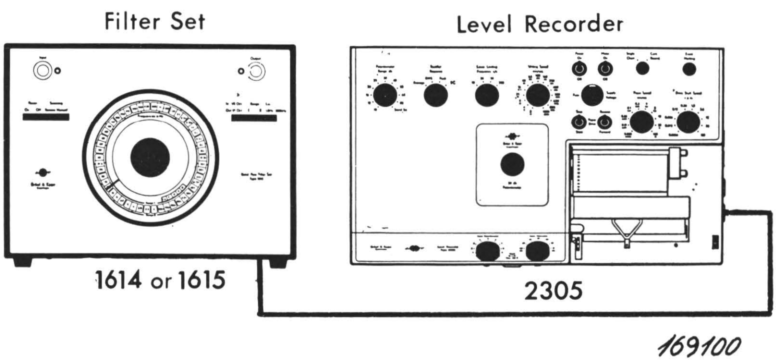


Fig.4.7 Filter Set Type 1614/15 combined with Level Recorder Type 2305 using remote control cable AQ 0019

2. Set control knobs on Level Recorder:

POTENTIOMETER RANGE dB"	"Stand by"
POWER	"On"
MOTOR	"On"
PAPER DRIVE	"Stop" and "Forward"

The switching moment of the Filter Switch on the Band-Pass Filter Set can now be synchronized with the paper movement.

1. Turn the screw S shown in Fig.4.8 with the aid of a screwdriver, until marking cut in the screw is in its upper position.
2. When proceeding from above set control knobs on the Microphone Amplifier and Band-Pass Filter Set as:
   Microphone Amplifier:

   FREQUENCY RESPONSE SWITCH respective WEIGHTING NETWORK to "External Filter"

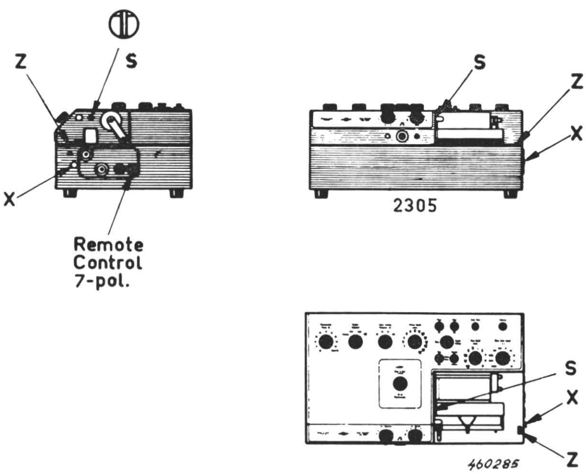


Fig. 4.8 Level Recorder Type 2305 with identification of Synchronising Gear Lever X, Screw S and Finger Wheel Z.

Filter Set:

POWER	"On"
SCANNING	"Manual"

1/3 or 1/1 octave bands switched in as desired.
Filter Switch to one step before (counter-clockwise) the position at which scanning should commence.

SCANNING	"Remote"

3. Set control knobs on the Level Recorder as follows:
Set PAPER DRIVE to "Stop".
Press pushbutton marked SINGLE CHART–CONT. RECORD.
The paper starts moving, and then the reference voltage commences to be recorded.
The pushbutton should be released when the paper has moved to about the "200" – "300" Hz (c/s) line.

4. Correct synchronization is obtained when the switching over from the "80" Hz (c/s) to the "100" Hz (c/s) filter takes place on the "90" Hz (c/s) line only, refer Fig. 4.9

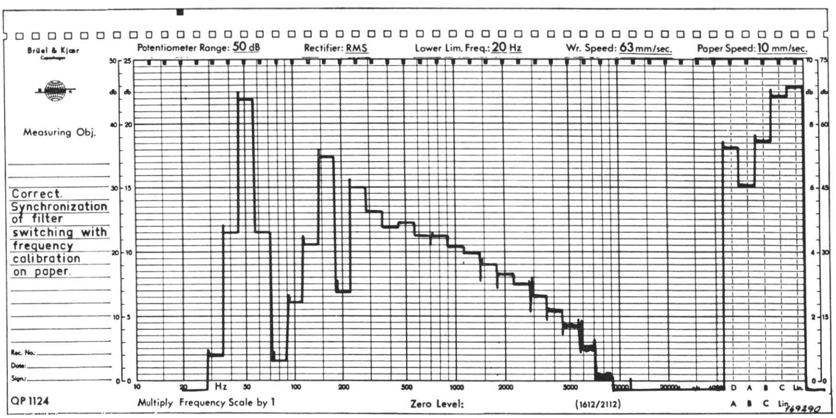


Fig. 4.9 Correct Synchronisation between Recording Paper and Filter Switching

To ensure that synchronization is achieved within the proper 1/3 octave filter the component of the power supply fundamental frequency should be represented as the highest value on the spectrogram within the filter covering this fundamental. From Fig.4.9 it is seen that the fundamental (here 50 Hz (c/s)) is the highest value and rests within the filter concerned. In the case of a 60 Hz (c/s) power supply frequency the highest value would be contained within the 63 Hz (c/s) filter.

5. If the synchronization is incorrect, the paper should be shifted by the finger wheel Z.

NOTE: To avoid the effect of play between the gear wheels, the paper should always be shifted in a manner, so that it approaches the correct point in the reverse direction. If, for example, it has to be shifted corresponding to a higher frequency, i.e. forward direction, the paper is shifted a little beyond, and finally reversed to the desired point.

To be able to see how far the paper has to be shifted, it is recommended to draw a line by means of the stylus, when the paper has stopped. By using this line, the paper is now shifted the required distance to give correct synchronization, this being easily seen from the previous recording. To draw the line, the stylus is given a deflection which may be obtained by pressing the knob "100 mV. Ref." on the Level Recorder. Should the paper have to be shifted equal to a lower frequency the respective distance may be marked on the paper beforehand.

6. To check the synchronization, run the recording to about the "2000" – "3000" Hz (c/s) line. When synchronized correctly the switching from the "800" Hz (c/s) to the "1000" Hz (c/s) filter should now take place at the "900" Hz (c/s) line.
7. PAPER DRIVE is set to "Start", whereby the paper moves to the pre-selected single chart stop.

   The single chart automatic stop and the synchronization have now been completed. The combined Pass-Band Filter Set and the Level Recorder can then be inserted in the desired measuring arrangement.

9. MEASURING ERRORS

When making measurements the response of the measuring system must be taken into account in assessing the accuracy of the results obtained. In a measuring system employing the filter Set Type 1614/15 and the Level Recorder Type 2305 the accuracy of the data obtained is dependent on the filter transient time and the averaging time of the Recorder. The more important of these two factors is the latter.

The Averaging Time of the Level Recorder is controlled by the setting of the "WRITING SPEED CONTROL". The setting of the "**Potentiometer** range dB" also influences the effective averaging time. The RMS fluctuations in measurements using the Level Recorder and the Filter Set depends on the averaging time of the Recorder and the bandwidth of the filter employed. A simple relationship exists:

$$\epsilon = \frac{1}{2\sqrt{\Delta f\ T}}$$

where ϵ is a measure of the statistical RMS fluctuations, Δ f is the frequency bandwidth (or measurement bandwidth) whichever is the smallest' and T is the averaging time. To minimise the error involved in trying to average these fluctuations for any particular 1/3 octave band and also cut down time consuming calculations it is to be suggested that the level should be taken where the fluctuations are most dense. When using the most commonly employed potentiometer (50 dB) the inherent error will be $\simeq$ 1–2 dB (the width of the trace $\simeq$ 1 dB). The slowest writing speed, however, should always be employed except when time considerations enter into the measurements, the question of a suitable filter scanning speed is brought up. This scanning speed is a direct function of the Level Recorder Paper Speed. If a Level Recording is made the recorder stylus at each 1/3 octave band has to move to a new level. The maximum scanning speed can therefore be ascertained from this. If we assume that the stylus has to traverse at the most the paper width (100 mm) before the next filter is switched in then the paper speed $\leq$ 0.05 x writing speed. (The width of 1/3 octave band is 5mm).

5. TYPICAL MEASUREMENT AND ANALYSIS SET–UPS USING THE TYPES 1614/15

DIRECT ANALYSIS OF SOUND

Sound analysis in 1/3 octave or octave bands can be done with the set-up of Fig.5.1. The 1615 covers the whole audible frequency range. The 1614 is only necessary if more than the audible range has to be analysed. The Set-up shown is also a precision sound level meter in the linear ranges of the Filter Set.

The addition of the Level Recorder Type 2305 allows the sound spectra to be automatically recorded on precalibrated paper. A typical sound spectrogram is shown in Fig.5.2.

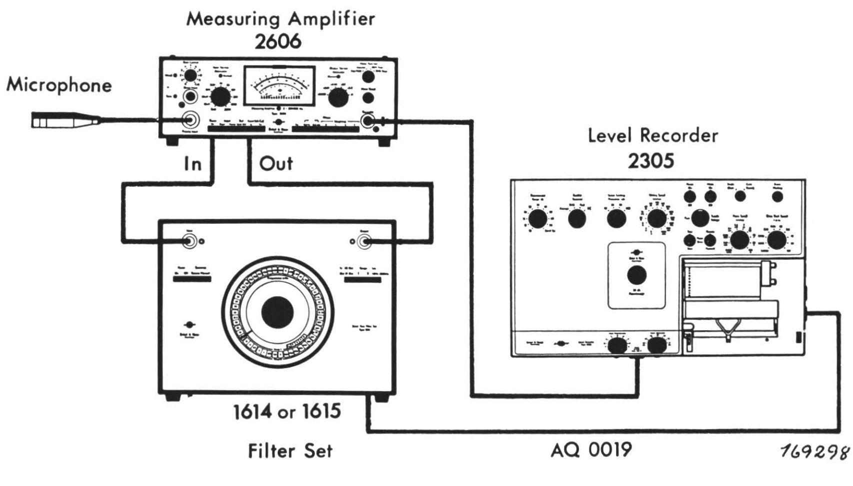


Fig.5.1 Set-up for direct analysis of Sound

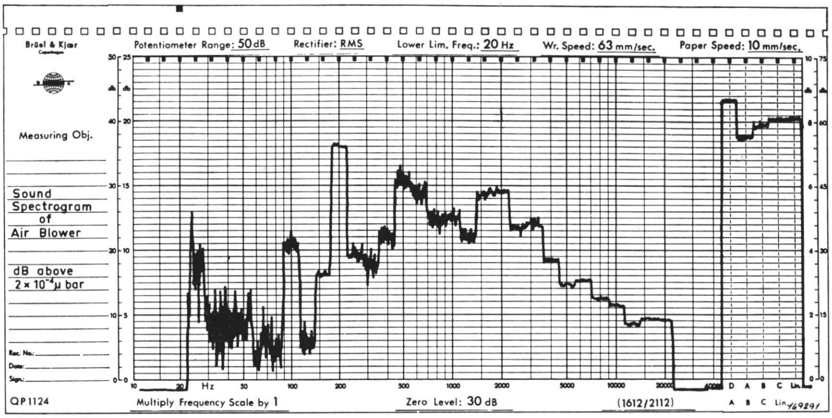


Fig.5.2 Typical Sound spectrogram produced by 1/3 octave analysis

DIRECT ANALYSIS OF VIBRATION

The Type 1614 may be found more useful for vibration spectra because of the greater frequency range. Otherwise the set-up is similar to the one for sound spectra, except that the microphone is replaced by an accelerometer and preamplifier (Fig.5.3). The 2606 scale can be changed to read acceleration directly.

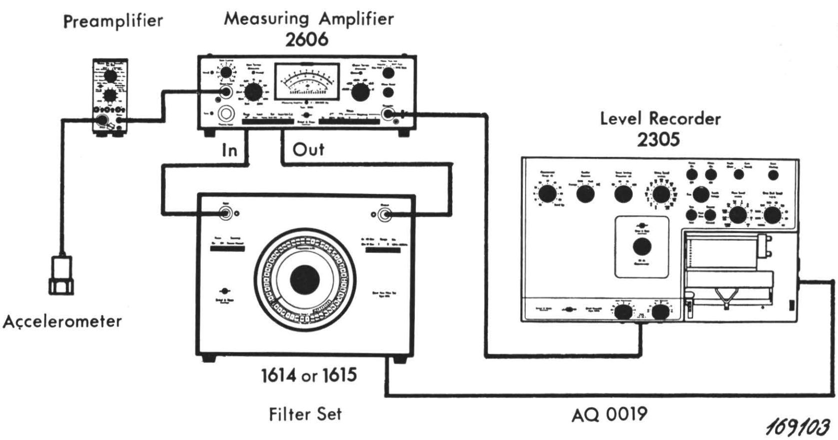


Fig.5.3 Set-up for direct analysis of Vibration

BANDS OF RANDOM NOISE

Bands of random noise are often used to produce more realistic conditions for loudspeaker tests, sound insulation tests, reverberation, etc.
Bands of Random Noise may be generated with the combination of 1614 or 1615 and the B & K Random Noise Generator Type 1402. Octave or 1/3 octave bands can be generated for excitation of, for instance, a loudspeaker with a constant output power at all frequencies. The 1402 has a 3 dB/octave weighting network which compensates for the increase of power with frequency which occurs when constant percentage bandwidths of noise are used.

ANALYSIS FROM TAPE RECORDER

The 1614/15 Filter Sets can be used to directly analyse the output from a tape recorder. The B & K Type 7001, with maximum signal of 1 V RMS is suitable for direct connection to the input of the Filter Set. For recording of spectrograms, the Level Recorder Type 2305 can be synchronized with the Filter Set.

LOW FREQUENCY ANALYSIS

The Type 7001 Tape Recorder has a frequency response down to DC, and it may sometimes be required to frequency analyse down to very low frequencies from the tape. This can be done by means of frequency transformation with the tape recorder. The tape is simply played back at a faster speed, so that all frequencies are multiplied by the ratio of the playback to recording speed. Frequency ratios up to 40:1 are available from the 7001, so that for the 2 Hz filter of the 1614, 0.05 Hz components can be analyzed with frequency transformation.

ANALYSIS OF TRANSIENTS

Signals of short duration, pulses, transients, etc. can be recorded on the 7001 and frequency analyzed with the Filter Set by making use of the tape loop adaptor. The signal is either recorded onto the tape loop directly, or else a piece from a continuous tape is selected and made into a loop. By combining this technique with that of frequency transformation, analysis in the range 0.05 Hz - 20 kHz is possible, of pulses, transients etc.
The technique is to repeat the signal by means of the loop adaptor, as often as is required for analysis. Normally this means repeating it once for each filter of the filter set. Provision is made in the 7001 to do this automatically in conjunction with the Filter Set and a Level Recorder Type 2305.

RECORDING OF LOW FREQUENCY SOUND

If low frequency sounds are to be analysed, they are best recorded first on the tape recorder. Then frequency transformation etc. as described above can be used. To record sounds lower in frequency than 2 Hz, the B & K Type 4146 microphone, in conjunction with the B & K Microphone Carrier System Type 2631 will be required and is shown in Fig.5.4. The 4146 microphone has a guaranteed response down to 0.1 Hz, and is suitable for investigating sonic boom, thunder, and other low frequency sound phenomena.

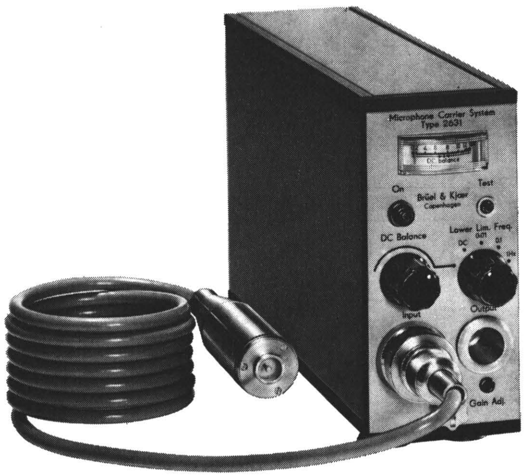


Fig.5.4 Low frequency sounds down to 0.1 Hz can be recorded with the Microphone Carrier System Type 2631.

Exact Centre Frequency f_o	Nominal Centre Frequency	Band-edge Frequencies f_1 and f_2	Pass-band
1.00000	1.0	F_1 0.89125 F_2 1.12202	0.23077
1.25893	1.25	F_1 1.12202 F_2 1.41254	0.29052
1.58489	1.6	F_1 1.41254 F_2 1.77828	0.36574
1.99526	2.0	F_1 1.77828 F_2 2.23872	0.46044
2.51189	2.5	F_1 2.23872 F_2 2.81839	0.57967
3.16228	3.15	F_1 2.81838 F_2 3.54814	0.72976
3.98107	4.0	F_1 3.54813 F_2 4.46684	0.91871
5.01187	5.0	F_1 4.46683 F_2 5.62342	1.15659
6.30957	6.3	F_1 5.62341 F_2 7.07947	1.45606
7.94328	8.0	F_1 7.07945 F_2 8.91252	1.83307
10.00000	10.0	F_1 8.9125 $F_2$11.2202	2.3077

6. USEFUL FILTER INFORMATION AND DEFINITIONS

IDEAL FILTER (BAND-PASS)

An ideal bandpass filter is one which displays zero attenuation in the pass band and infinite attenuation at any other frequency.

i.e. If the pass band extends from f_1 to f_2,

$$\alpha = 0 \qquad f_1 < f < f_2$$

$$\text{and} \quad \alpha = \infty \qquad f < f_1, \quad f > f_2$$

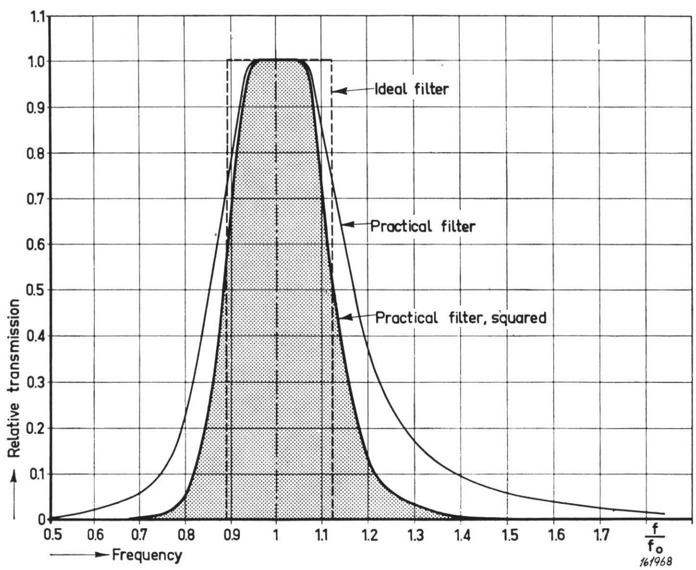


Fig.6.1 Concept of Effective Bandwidths and Ideal Filter

EFFECTIVE BANDWIDTH

The total integrated random white noise power passed by the practical filters is equal to that which would be passed by an ideal 1/3 octave filter. The white noise power passed by such a filter is given by:

$$(2^{1/6} - 2^{-1/6})\ fm\ Pm \text{ or } 0.2316\ Fm\ Pm$$

where Pm is the noise power per unit frequency of the filter midband frequency fm.
Due to tolerances in filter production, the tolerance of the effective bandwidth of a practical filter is ±10% (approx. ±0.4 dB). The effective bandwidth concept is illustrated in Fig.6.1.
Since the noise power is proportional to the square of the noise voltage, the amplitude response of the filter is squared and then the area under this curve (shaded) is equal to the area of the rectangle which represents the ideal filter frequency characteristic.

OCTAVE

An octave is the interval between two pure tones having a frequency ratio of 2.
Other frequency intervals can also be expressed as a number of octaves n, where n can be any value. Then the interval between the frequencies f″ and f′ is given by

$$\frac{f''}{f'} = 2^n \text{ or } n = \log_2 \frac{f''}{f'}$$

When n is negative, f″ is said to be n octaves below f′, and when n is positive, f″ is said to be n octaves above f′.

OCTAVE		Frequency ratio up	Frequency ratio down
1/12	0.0833	1.0594	0.9439
1/8	0.1250	1.0905	0.9170
1/6	0.1667	1.1225	0.8909
1/4	0.2500	1.1892	0.8409
1/3	0.3333	1.2591	0.7937
1/2	0.5000	1.4142	0.7071
2/3	0.6667	1.5871	0.6303
3/4	0.7500	1.6817	0.5946
1	1.0000	2.0000	0.5000
	n	2^n	2^{-n}

FILTER CENTRE FREQUENCY

The centre frequency of a pass-band filter is the geometric mean of the band-edge frequencies.

$$f_c = \sqrt{f_1 \; f_2}$$

where f_c = Filter centre frequency and f_1, f_2 are the band-edge frequencies.

FILTER BAND-EDGE FREQUENCIES

The band-edge frequencies are the frequencies at which the response of the filter is a certain value lower than the maximum response.
Usually this value is chosen to be 3 dB but it can be defined as required. In the case of the 1614/15 Filter Set for instance,–3.7 dB is quoted, so that the bandwidth of each filter is 1/3 octave at the –3.7 dB points and this is also then the effective bandwidth.

BANDWIDTH

The bandwidth of a band–pass filter is the value (in Hz of octaves) the difference between the upper and lower band-edge frequencies.

$$\text{i.e. } B = f_2 - f_1$$

$$\text{or } b = \log_2 \frac{f_2}{f_1} \text{ octaves}$$

Bandwidth is sometimes also expressed as a percentage of the passband centre frequency.

SPECTRUM

The spectrum of a function of time is a description of its resolution into components, each of different frequency.

Continuous Spectrum A continuous spectrum is a spectrum in which the components are continuously distributed over a frequency region.

White Noise Spectrum A white noise spectrum is a continuous spectrum with a constant spectrum density (mean square

	amplitude per unit frequency) over a specified frequency range.
Line Spectrum	A line spectrum is a spectrum consisting of discrete single frequency components.

NOISE

White Noise	See White Noise Spectrum.
Pink Noise	Pink noise is a noise whose spectral density decreases at a rate of 3 dB per octave over a specified frequency range.
Random Noise	The instantaneous magnitude of a random noise signal is specified only by a probability distribution function. If the distribution function is Gaussian, the random signal is called "Gaussian random noise".

SPECIFICATIONS 1614/15

Frequency Range:

Selective range I:	22.4 Hz – 22.4 kHz
Selective range II:	1.8 Hz – 180 kHz (1614 only)
Linear range	
50 position switch :	22.4 Hz – 22.4 kHz
push button :	1.8 Hz – 200 kHz

Band-pass Filters:

In accordance with IEC publication 225 - 1966 and ANSI S1.11-1966. and DIN 45 652 (for 1/3 octave filters)

Centre-frequencies:	
1/3 octave:	2 Hz – 160 kHz (50 filters)
1/1 octave:	4 Hz – 125 kHz (16 filters).
Attenuation outside pass-band:	
1/3 octave:	Better than 75 dB at 5 x and 1/5 centre-frequency.
1/1 octave:	Better than 60 dB at 8 x and 1/8 centre-frequency.
Attenuation in central pass-band:	0 dB ± 0.5 dB
Max. peak-to-valley ripple:	
1/3 octave:	0.5 dB.
1/1 octave:	1.5 dB.

Linear Filters:

Attenuation in pass-band:	0 dB ± 0.25 dB at 1 kHz ref.
Pushbutton:	1.8 Hz–180 kHz, ± 0.1 dB 180 Hz–200 kHz, + 0,–0.5 dB
Slope above pass-band:	36 dB/octave
50 position switch:	22.4–22.4 kHz, ± 0.5 dB
Slope outside pass-band:	24 dB/ octave

Filters for Sound Level Measurements:

Curve A, B, C:	In accordance with IEC standard for precision sound level measurements. (IEC 179, 1965).

Curve D:	In accordance with proposed standard.
Input Impedance:	125 kΩ in parallel with 55 pF.
Input Voltage:	Nominal 1 V RMS. Max. 5V peak.
Distortion (Amplifiers):	
Input amplifiers:	0.01 % with 1 V RMS input 0.05 % with 5 V peak input
Total for input and output amplifiers, in position Lin. (1.8 Hz – 200 kHz):	0.1 % with 1 V RMS input 0.5 % with 5 V peak input
Distortion (Filters):	
Active filters (2 - 200 Hz):	Less than 0.3 % with 1 V RMS input Less than 1 % with 5 V peak input
Passive filters (250 Hz – 160 kHz):	Less than 0.1 % with 1 V RMS input Less than 0.3 % with 5 V peak input
Output	
Output impedance:	600 Ω
Min. load impedance:	600 Ω (Attenuation in passband 6 dB ±0.25 dB)
Noise (50 kΩ across input):	
1/3 octave:	Less than 180 μV
1/1 octave:	Less than 1 mV.
Power Supply:	100.115.127.150.220.240. V AC 50–400 Hz. 16 W Also 12 V DC. 1.5 A.
Supply for Filter Switch	24 V DC, 0.180 A
Cabinet:	Supplied in A,B, or C model.
Dimensions: (Cabinet A):	Height 28 cm (11 ins) Width 38 cm (15 ins) Depth 20 cm (7.9 ins)
Weight:	13.5 kg (29.8 lb) approx.

Accessories Supplied:

2 x JP 0018	Coaxial Plug
1 x AN 0008	Mains cable (European)
1 x AQ 0019	Control cable to 2305
3 x VF 0009	0.35 A fuse
3 x VF 0010	2 A fuse
1 x JP 4701	3-pin plug
1 x JP 4705	6-pin plug
1 x BA 0020	Instruction manual
2 x BS 1271	Scale—lamp
1 x QA 0048	Allen Key 2 m/m

Other Accessories:

Extension printed circuit cards for servicing:

AR 0101
AR 0102
AR 0103

B & K INSTRUMENTS:

ACOUSTICAL....
Condenser Microphones
Piezo-Electric Microphones
Microphone Preamplifiers
Microphone Calibration Equip.
Sound Level Meters
(general purpose-precision-
and impulse)
Standing Wave Apparatus
Tapping Machines
Noise Limit Indicators

ELECTROACOUSTICAL....
Artificial Ears
Artificial Mouths
Artificial Mastoids
Hearing Aid Test Boxes
Telephone Measuring Equipment
Audiometer Calibrators
Audio Reproduction Test Equip.

STRAIN....
Strain Gauge Apparatus
Multipoint Panels
Automatic Selectors
Balancing Units

VIBRATION....
Accelerometers
Accelerometer Preamplifiers
Accelerometer Calibrators
Vibration Meters
Magnetic Transducers
Capacitive Transducers
Vibration Exciter Controls
Vibration Programmers
Vibration Signal Selectors
Mini-Shakers
Complex Modulus Apparatus
Stroboscopes

GENERATING....
Beat Frequency Oscillators
Random Noise Generators
Sine-Random Generators

MEASURING....
Measuring Amplifiers
Voltmeters
Deviation Bridges
Megohmmeters

ANALYZING....
Band-Pass Filter Sets
Frequency Spectrometers
Frequency Analyzers
Real-Time Analyzers
Slave Filters
Psophometer Filters
Statistical Analyzers

RECORDING....
Level Recorders
(strip-chart and polar)
Frequency Response Tracers
Tape Recorders

BRÜEL & KJÆR
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