2010

Instructions and Applications

Heterodyne Analyzer Type 2010

A versatile precision instrument for narrow band analysis of sound, vibration or voltage over the range 2 Hz to 200 kHz. It features automatic or remote switching of bandwidth and averaging time. Linear, A, B, C, and D weighting networks are included. The Beat Frequency Oscillator section produces a sinusoidal output at the tuning frequency and may be automatically regulated by a compressor loop.

BRÜEL & KJÆR

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HETERODYNE ANALYZER TYPE 2010

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CONTENTS

1. INTRODUCTION

The 2010 Heterodyne Analyzer is an extremely versatile precision instrument for analysis of sound, vibration or voltage over the range 2 Hz to 200 kHz.

The 2010 is basically a wide range linear measuring amplifier plus a beat frequency oscillator section, plus a continuously variable heterodyne slave filter with 6 selectable constant bandwidths.

The measuring amplifier section contains an RMS rectifier, accurate for signals with crest factor up to 5, with selectable RC effective averaging times from 0.1 to 100 secs. AC, and linear or logarithmic DC outputs are available. The lin-log converter allows lin or log meter indication.

The tuning frequency may be controlled mechanically, (for example, by the Level Recorders 2305 or 2307), or electrically, (for example, by the 2307) permitting the automatic recording of an analysis or a frequency response.

A log or lin frequency sweep may be selected.

The generator section (B.F.O.) has an output adjustable in 10 dB steps between 100 μV and 10 Volts and continuously variable within each 10 dB. The output frequency is that of the tuning frequency. The B.F.O. has a compressor circuit with adjustable compressor speed for automatic regulation of the output voltage.

Internal B & T programmes may be selected which enable the bandwidth and the effective averaging time of the rectifier circuit to be varied with frequency at fixed transition points. These programmes may also be remotely controlled.

Additional features include a 6 digit Nixie display for accurate frequency reading, automatic frequency control (A.F.C.) available with the 4 lower bandwidths, bandwidth compensation for power spectral density measurements, and tuning signal outputs for use with the B & K Heterodyne Slave Filter Type 2020.

The 2010 also contains the internationally standardized sound level meter frequency weighting networks A, B, C and D and "Fast" and "Slow" meter damping characteristics. These enable the 2010 to be used as a precision sound level meter which complies to the requirement of I.E.C. Recommendation 179 when used with a suitable condenser microphone and preamplifier.

The information contained in this Instruction Manual applies to instruments with serial numbers 357562 onwards.

2. CONTROLS

2.1. FRONT PANEL

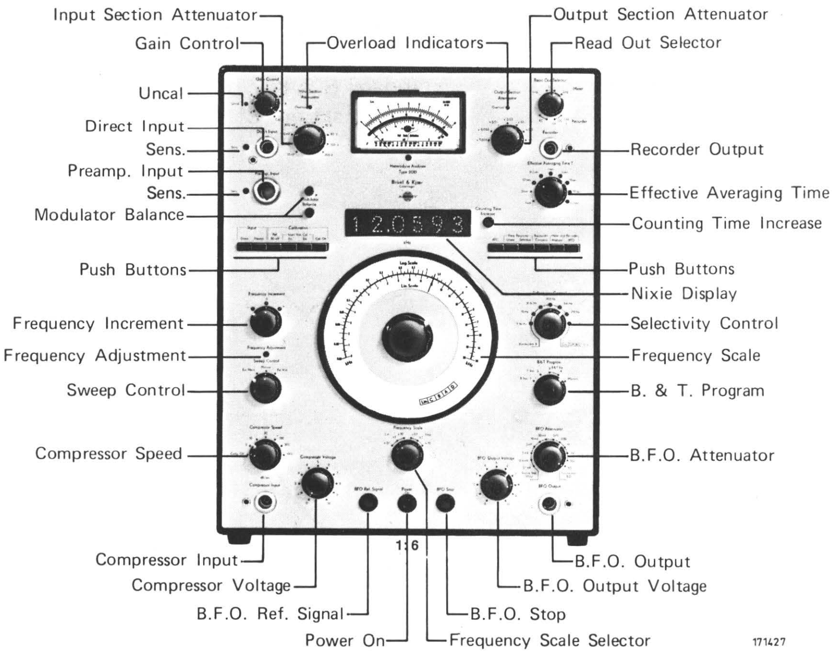

Fig.2.1. Front Panel of 2010

POWER: On/off switch for mains supply.

2.1.1. Measuring Amplifier Section

METER SCALE: Depress the retaining clip and tilt the glass panel forward to change the scale; see section 10.4 for scales available.

DIRECT INPUT: Coaxial socket input to the input amplifier. Input impedance, 1 MΩ//80 pF. The socket accepts the standard B & K coaxial plug JP 0101.

PREAMP. INPUT: 7 pin socket for connection of B & K microphones via their preamplifiers. The socket provides the necessary voltage supplies for the preamplifiers and a 200 V polarization voltage for condenser microphones. Input impedance 900 kΩ//80 pF. The socket accepts the standard B & K 7 pin plug JP 0701. The pin connections of the socket are shown in Fig.2.2.

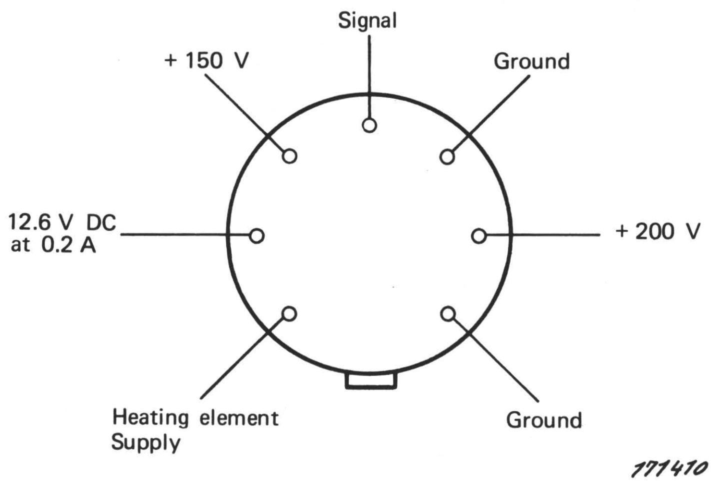

Fig.2.2. Pin connections of the Preamplifier input socket (Viewed Externally)

SENS.: A screwdriver operated potentiometer situated at the side of each input. It adjusts the gain of the input amplifier in order to compensate for different transducer sensitivities. The two adjusters work independently of each other and each has a range of about 10 dB.

A row of push-buttons is situated directly below the "Direct" and "Preamplifier" inputs. Their functions are as follows.

INPUT:	"Direct" input or input via an external "Preamplifier" may be chosen by depressing the appropriate push button.
CALIBRATION:	
"Ref. 50 mV"	Supplies the 50 mV RMS 1 kHz sine-wave signal for internal calibration purposes.
"Insert Volt. Cal."	Choice of internal or external signal. The internal signal is 50 mV from the 1 kHz sine wave generator. "External" is for connection of an external frequency generator, see Section 3.2.4.
"Cal. Off"	For reset of the other calibration buttons to a passive position.
GAIN CONTROL:	For continuous control of the gain of the first amplifier. When in position "Cal" the gain is fixed. Maximum attenuation approx. 10 dB.
UNCAL.:	This light is lit when the GAIN CONTROL knob is not in the "Calibrated" position.
INPUT SECTION ATTENUATOR:	For attenuation of input signal by 10 dB steps. Voltages marked around the knob show the maximum RMS input voltage (for full scale deflection) for each knob setting. By using the GAIN CONTROL, input voltages up to 700 V peak can be measured. See section 4.1.2.
OVERLOAD INDICATORS:	These indicate overload in input or output amplifiers. While the lamp is lit the meter reading is inaccurate and less than the correct value.

OUTPUT SECTION
ATTENUATOR: Stepped attenuator (10 dB steps) for attenuation of the signal level between filter outputs and the output amplifier. To ensure the best possible signal-to-noise ratio the knob should be kept as far clockwise as possible.

READ OUT SELECTOR: A four position switch which provides:

a) A choice between a "Lin" or "Log" meter display, and

b) A choice between an AC signal direct from the amplifier or a linear or logarithmic DC signal from the rectifier.

RECORDER: Output socket for AC or DC recording.

EFFECTIVE AVERAGING TIME: For the selection of integrating time constants to give effective averaging times ranging from 0.1 to 100 secs. The first two positions "Fast", "Slow" correspond to the IEC standard for precision sound level meters.

2.1.2. Filter Section

MODULATOR BALANCE: The two potentiometers balance the first mixer to suppress the unwanted frequency from the V.C.O. for low frequency analysis. See section 3.1.3.

FREQUENCY DISPLAY: A six digit Nixie display shows the tuned in frequency in kHz.

COUNTING TIME INCREASE: When the push button is depressed, the frequency sampling rate of the Nixie display is increased by 10, providing an extra digit on the Nixie display.

A row of push buttons is situated directly below the EFFECTIVE AVERAGING TIME switch. Their functions are as follows:

A.F.C.: Automatic Frequency Control phase detector circuit. The A.F.C. is active only in the four lower bandwidths (3.16 to 100 Hz), see section 5.5.

FREQUENCY RESPONSE:

"Linear" — The input signal is not filtered and the response is flat ± 0.5 dB between 2 Hz to 200 kHz.

"Selective" — The input signal is filtered either by the analyzer or by an external filter.

"Bandwidth Comp." — Allows bandwidth compensation for power spectral density measurements. Compensation = $\frac{1}{\sqrt{B}}$; B = Bandwidth (Hz).

METER AND RECORDER:

"Analyzer" — If the button is depressed, the output signal voltage from the analyzer is indicated on the meter. The output of the analyzer is fed to the RECORDER output:

"B.F.O." — If the button is depressed, the output signal voltage from the B.F.O. is indicated on the meter. The meter full scale deflection is indicated by the position of the B.F.O. ATTENUATOR switch. The output voltage is fed to the RECORDER output:

FREQUENCY SCALE: The outer scale is logarithmic and extends over 3 decades from 20 Hz to 20 kHz (see also FREQUENCY SCALE RANGE SWITCH).

The inner scale is linear from 0 Hz to 20 kHz.

The central knob enables a mechanical sweep (manual or external drive) to be made. The standard weighting network filters A, B, C and D, or a linear response (2 Hz – 200 kHz) may be selected by the scale pointer, unless an external filter is selected.

FREQUENCY SCALE RANGE SWITCH:	A six position switch which selects either the linear or logarithmic (inner or outer) frequency scale, and gives the choice of three scale factors, x 0.1, x 1 and x 10.
FREQUENCY INCREMENT:	A ten-turn potentiometer which allows fine adjustment around a selected frequency. Three lights above the knob indicate whether the actual frequency is above, below or equal to the frequency selected on the scale.
FREQUENCY ADJUSTMENT:	A screwdriver operated potentiometer which allows adjustment of 2, 20, or 200 Hz according to scale factor. For compensation of long term drift of the V.C.O. at low frequencies, see Section 3.1.2.
SWEEP CONTROL:	A three position switch which selects: a) "Ext. mech".: An external mechanical drive may be used to sweep the scale. b) "Manual": The scale may be swept manually. c) "Ext. Volt.": The frequency may be swept by an external voltage connected at the rear panel socket, FREQUENCY CONTROL VOLTAGE "In".

Note: The scale can not be swept manually while the sweep control is in the "Ext. mech." position.

SELECTIVITY CONTROL: Six different bandwidths may be chosen. The "Ext. Filter" position enables an external filter to be connected. On this "Ext. Filter" position, the internal A, B, C, D and lin. filters are not operative.

B & T PROGRAM: A five position selector switch which enables programmes of bandwidths and/or averaging times to be chosen. The manual position enables a single bandwidth and averaging time to be chosen using the SELECTIVITY CONTROL and the EFFECTIVE AVERAGING TIME selector. See section 5.3.5.

2.1.3. Beat Frequency Oscillator (B.F.O.) Section

B.F.O. OUTPUT VOLTAGE: Potentiometer which gives continuous adjustment of output signal when the compressor circuit is not in operation.

B.F.O. ATTENUATOR: The selector gives the choice between a direct output (output impedance 5 Ω) 0 to 10 volts, or an attenuator output, variable from 100 μV to 10 V in 10 dB steps. The output impedance in the attenuator mode is 600 Ω. Matching impedance 140 Ω.

B.F.O. OUTPUT: The output signal is fed from the oscillator section through this socket. The socket accepts the standard B & K plug JP 0101.

B.F.O. STOP: A noiseless push-button switch to interrupt the oscillator. The oscillator restarts when the button is released.

B.F.O. REF. SIGNAL: When the push-button is depressed, a 100, 1000, or 10,000 Hz reference signal, according to scale factor, is produced at the voltage selected on the B.F.O. ATTENUATOR and B.F.O. OUTPUT VOLTAGE controls.

COMPRESSOR INPUT: For connection of the signal from a regulating transducer when automatic regulation of the B.F.O. output is required. The input voltage must be at least 0.5 Volts.

COMPRESSOR SPEED: Selects the time constant in the regulation circuit. Gives regulation speeds between 3 and 1000 dB/sec.

COMPRESSOR VOLTAGE: Logarithmic potentiometer for control of the output voltage of the instrument when the compressor loop is applied.

2.2. REAR PANEL

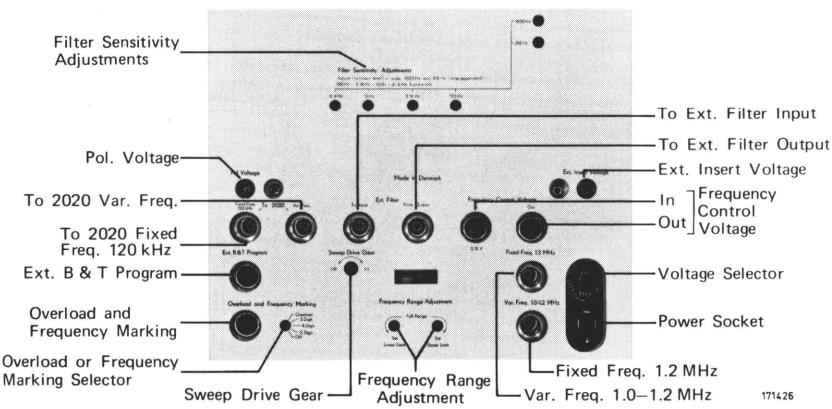

Fig.2.3. Rear Panel of 2010

FILTER SENSITIVITY ADJUSTMENTS:

Six screwdriver operated potentiometers for adjustment of the transmission level of the filters. (See Preliminary adjustments and calibration, Section 3.1.4).

POL. VOLTAGE:

Sockets for measurement of polarization voltage. Measurement should be made with an external D.C. voltmeter having a rating of at least 20 kΩ/Volt. The ground socket is on the right.

EXT. INSERT VOLTAGE:

Sockets for input signal from external generator for insert voltage calibration of condenser microphones. Load impedance 10 kΩ. The socket on the left is ground.

TO 2020:

These sockets supply control voltages of 120 kHz, and 100 – 120 kHz for the B & K Heterodyne Slave Filter Type 2020. The output impedances are 100 Ω, and the output levels are approximately 200 mV. Only the scale factor "x 1" on the 2010 is usable. (See Section 6.3).

EXT. FILTER:

"To Input"/"To Output"

These sockets are for connection to an external filter and accept the standard B & K plugs JP 0101. The input impedance is approx. 150 kΩ, the output impedance is less than 25 Ω.

FREQUENCY CONTROL VOLTAGE:

The input socket ("In") is for connection of a DC voltage between 0 and 10 Volts for control of the V.C.O. when the External voltage mode ("Ext. Volt") is chosen on the SWEEP CONTROL (front panel). The output socket ("Out") delivers:

a) A voltage proportional to the position of the pointer on the frequency scale or

b) A voltage equal to the frequency control input voltage when the 2010 is driven in the "Ext. Volt" mode. The pin connections of the sockets are shown in Fig.2.4.

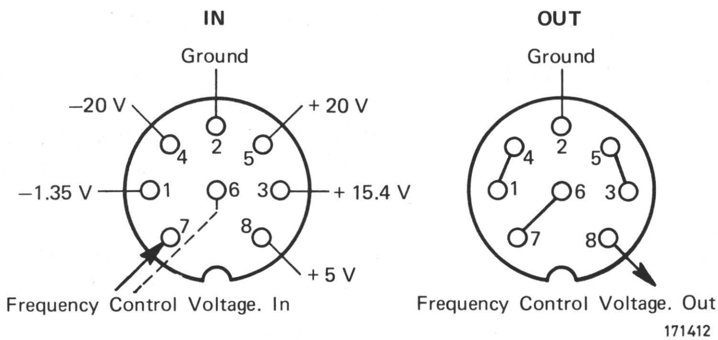

Fig.2.4. Pin connections of the Frequency Control Voltage sockets, (Viewed Externally)

EXT. B & T PROGRAM: An eight pin socket for remote control of the Bandwidth and/or Effective Averaging Time (See section 4.6.2.).

SWEEP DRIVE GEAR: A screwdriver operated switch which selects a 10:1 gear box to reduce the frequency scanning speed when driven by an external mechanical drive. This enables the drive shaft cable to rotate at a faster relative speed to reduce the effect of mechanical sticking and ensure a smooth response.

OVERLOAD AND FREQUENCY MARKING: A 7 pin socket for connection to the Type 2305 or 2307 Level Recorder. The Event Marker Pen registers either an overload condition or a change in a digit on the Nixie frequency display. The screwdriver operated switch to the right of the socket enables a change in either the 3rd, 4th or 5th digit from the left on the Nixie display to be recorded (see section 5.3.3). The pin connections of the socket are shown in Fig.2.5.

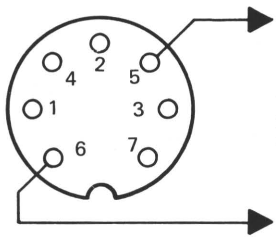

Fig.2.5. Pin connections of the Overload and Frequency Marking socket, (Viewed Externally)

FREQUENCY RANGE ADJUSTMENT:

Two screwdriver operated potentiometers which can be used to limit the frequency range of the Voltage Controlled Oscillator (V.C.O.) output, which limits the B.F.O. frequency range. Mechanical movement of the scale pointer is not restricted but the oscillator output and the Nixie display are switched off. The output from the FREQUENCY CONTROL VOLTAGE "Out" Socket is unaffected.

FIXED FREQ. 1.2 MHz and VAR. FREQ. 1.0–1.2 MHz

Control voltages for other external equipment.

VOLTAGE SELECTOR:

For selection of correct mains supply voltage, unscrew the central fuse, and turn the switch using a coin or a wide bladed screwdriver. The fuse is 250 V, 500 mA rated.

POWER SOCKET: Socket for connection of A.C. mains supply. For connection see Fig.2.6.

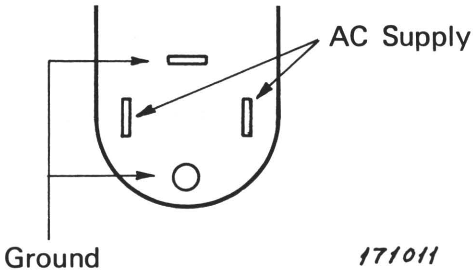

Fig.2.6. A.C. Power Socket

2.3. SIDE PANELS

A drive shaft socket is situated on each side of the 2010. The socket on the left of the instrument (when facing the 2010 front panel), is intended to receive one end of the drive shaft UB 0041 when the scanning mechanism of the 2010 is mechanically driven by one of the B & K Level Recorders Types 2305 or 2307.

Driving the 2010 in this way will sweep the frequency scale pointer clockwise. (i.e. in the direction of increasing frequency).

The socket on the right panel, is mainly intended as an auxiliary drive source when the 2010 is already being mechanically driven. However, this socket may be used for driving the 2010, should a decreasing frequency sweep be required. In this case, the left panel socket becomes an auxiliary drive source.

3. PRELIMINARY ADJUSTMENTS AND CALIBRATION

3.1. PRELIMINARY ADJUSTMENTS

3.1.1. General

Before the instrument is switched on, ensure the voltage selector is set to the correct line voltage. If not, unscrew the central fuse, and turn the selector to the desired position with a coin or wide bladed screwdriver.

If necessary, set the needle deflection to zero using the mechanical adjuster under the meter scale.

Switch on and allow a suitable length of time for the instrument to warm up; (i.e. a few minutes for normal use, and up to 1 hour if high stability of the V.C.O. is required).

3.1.2. Frequency adjustment

Set the controls as follows:

The SWEEP CONTROL selector to "Manual".

The FREQUENCY SCALE selector to "Log x 1".

The MAIN SCALE POINTER exactly to 0.02 kHz (the left hand end of the scale).

The FREQUENCY INCREMENT control should be in a neutral (zero) position, if not adjust until the middle lamp is lit.

Then the Nixie display should register 0.0200 kHz (the highest resolution should be selected by depressing the COUNTING TIME INCREASE push-button).

If the display does not register this frequency, adjust the FREQUENCY ADJUSTMENT potentiometer with a small screwdriver until this reading is obtained.

3.1.3. Modulator Balance

For low frequency analysis, i.e. if the centre frequency is lower than four times the bandwidth selected, it is necessary to adjust the balance in the first modulator in order to suppress the unwanted components from the mixer. The procedure is as follows:

Set

The FREQUENCY SCALE selector to range required.

The MAIN SCALE POINTER should be at the left hand end of the scale (as low a frequency as possible).

The INPUT selected may either be "Direct" or "Preamp.", but there should be *no* connection to the selected input.

The "Selective" mode on the FREQUENCY RESPONSE push-buttons should be selected, and the smallest bandwidth which encompasses "0" Hz selected on the SELECTIVITY CONTROL.

Depress the "Analyzer" push-button and switch the READ OUT SELECTOR to a "Lin" position. Then, turn the OUTPUT SECTION ATTENUATOR switch anticlockwise, until a significant deflection is obtained on the meter.

Turn the two modulator balance controls alternately until a minimum deflection is obtained on the meter. It may be necessary to turn the OUTPUT SECTION ATTENUATOR switch progressively anticlockwise.

Note: The balance procedure is not affected by the position of the INPUT SECTION ATTENUATOR switch.

3.1.4. Filter Sensitivity Adjustments

It is necessary to adjust the levels in the filters so that all the filters have the same relative attenuation at the centre frequency. The procedure is as follows:

Select "100 mV" position on the INPUT SECTION ATTENUATOR and "x 1" on the OUTPUT SECTION ATTENUATOR. The GAIN CONTROL knob should be in the calibration position.

Depress the "Analyzer" push-button, and switch the READ OUT SELECTOR to a "lin" position.

Select either input ("Direct" or "Preamp.") by depressing the appropriate push-button. Depress the "50 mV" push-button. Ensure the linear frequency response push-button (LINEAR) is depressed.

If necessary, adjust the SENS. adjustment of the chosen input, so that the scale pointer aligns with the reference point on the meter scale (if the scale used does not have a reference point, it may be convenient to align the pointer with a particular graduation).

Then depress the SELECTIVE mode push-button, and switch the SELECTIVITY CONTROL to 1000 Hz.

Position the frequency scale pointer at approx. 1 kHz and turn the frequency increment knob until a maximum deflection is obtained. Then, using the 1000 Hz level adjustment potentiometer on the rear panel, adjust the level so that the pointer again aligns exactly with the reference point (or with the chosen graduation mark).

Repeat the procedure for the 316 Hz bandwidth. As the 1000 Hz and 316 Hz level adjustments are interdependent, the 1000 Hz level adjustment must be repeated. The cycle is repeated until both levels are correctly adjusted.

The procedure is then repeated for the remaining bandwidths in the order 100 Hz, 3.16 Hz, 10 Hz, 31.6 Hz. The adjustment of these bandwidths is not dependent on any of the others, therefore it is necessary to adjust the level once only.

The SELECTIVITY CONTROL must be switched to the appropriate bandwidth each time.

3.1.5. Polarization voltage

Most of the B & K condenser microphones are designed to operate with a 200 V polarization voltage. This polarization voltage is provided at the "Preamp." socket of the 2010. The voltage is correctly set prior to dispatch from the factory. Terminals are provided on the rear panel for checking this voltage.

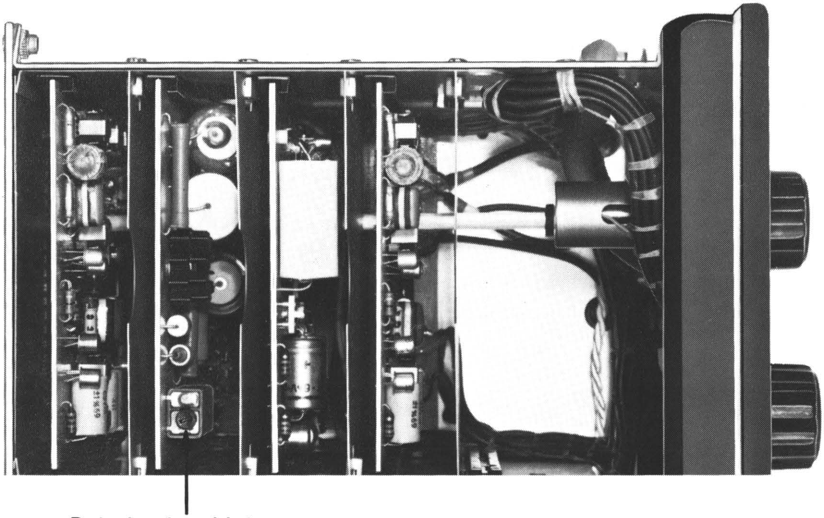

Fig.3.1. Polarization Voltage adjustment potentiometer

The voltage should be measured with a DC voltmeter with a rating of at least 20 kΩ/V. If necessary, adjustment is carried out using the potentiometer on circuit board ZG 0030 (Fig.3.1), situated in the lower half of the instrument. Access to the potentiometer is gained by removing the instrument case.

3.2. CALIBRATION

3.2.1. Calibration for Voltage Measurements

1. Carry out preliminary adjustments (section 3.1), if necessary.

2. Fit voltage scale (SA 0051, SA 0052 or SA 0054).

3. Set controls on 2010 to the following positions:

GAIN CONTROL	"Cal."
INPUT SECTION ATTENUATOR	"100 mV"
OUTPUT SECTION ATTENUATOR	"x 1"

EFFECTIVE AVERAGING TIME	"Fast"
READ OUT SELECTOR	"Lin", AC or DC

4. Select push-buttons:

REF. 50 mV	
INPUT	either "Direct" or "Preamp."
FREQUENCY RESPONSE	"Linear"

The needle should now deflect to the red mark on the scale, which indicates 50 mV. If necessary adjust the sensitivity potentiometer beside the appropriate input socket.

5. Repeat procedure for the other input if both inputs are required.

3.2.2. Calibration for Sound Measurements

Using a Known Sound Source

A known sound source can be provided using either the B & K Pistonphone Type 4220 (124 dB at 250 Hz) or the B & K Sound Level Calibrator Type 4230 (94 dB at 1000 Hz).

1. Carry out the preliminary adjustments, if necessary.

2. Fit the meter scale appropriate to the sensitivity of the microphone being used, see Table 3.1.

Microphone Open Circuit Sensitivity	B & K Microphone Type	Scale No.
26 – 80 mV per N/m^2	4131 4132 4144 4145 4146	SA 0056
5 – 26 mV per N/m^2	4133 4134 4117 4147	SA 0057
0.80 – 2.6 mV per N/m^2	4135 4136	SA 0060
0.26 – 0.8 mV per N/m^2	4138	SA 0083

Table 3.1. Microphone scales for use with the 2010

3. Plug the microphone and associated preamplifier into the appropriate input on the 2010.

4. Set the controls and push-buttons as follows:

GAIN CONTROL	"Cal."
OUTPUT SECTION ATTENUATOR	"x 1"
EFFECTIVE AVERAGING TIME	"Fast"
FREQUENCY RESPONSE	"Linear"
INPUT	As appropriate
READ OUT SELECTOR	"Lin", AC or DC

5. Set the INPUT SECTION ATTENUATOR so that 120 dB (for Pistonphone calibration) or 90 dB (for Sound Level Calibrator calibration) is indicated on the range setting indicators.

6. Apply the sound source to the microphone. Using the Pistonphone 4220 or the Sound Level Calibrator 4230 the meter should read* 124 or 94 dB respectively. If it does not, adjust the SENS. potentiometer beside the input socket that is being used until the correct deflection is obtained.

Using Internal Reference Voltage

1. Carry out the preliminary adjustments if necessary.

2. Fit the meter scale appropriate to the sensitivity of the microphone being used. (See Table 3.1).

3. Plug the microphone and associated preamplifier into the appropriate input on the 2010. Any microphone accessories can remain in position.

4. Set the controls as follows:

GAIN CONTROL	"Cal."
INPUT SECTION ATTENUATOR	"100 mV"
OUTPUT SECTION ATTENUATOR	"x 1"
EFFECTIVE AVERAGING TIME	"Fast"
READ OUT SELECTOR	"Lin.", AC or DC

---

* For the exact sound pressure, the Pistonphone Calibration chart or the Sound Level Calibrator manual should be consulted.

5. Select push-buttons:

FREQUENCY RESPONSE	"Linear"
INPUT	As appropriate
REF. 50 mV	

6. From the calibration chart of the microphone in use determine its Open Circuit Sensitivity in mV per N/m^2. This must be corrected for the attenuation and capacitive loading of the preamplifier. (Refer to the microphone and preamplifier instruction manuals).

7. Adjust the appropriate input SENS. potentiometer until the required sensitivity is indicated on the lower meter scale marked Open Circuit Sensitivity.

3.2.3. Calibration for Vibration Measurements

Using an Accelerometer Calibrator

Calibration may be carried out using the Accelerometer Calibrator Type 4291 or the Accelerometer Calibrator and Preamplifier Type 4292. Both calibrators can provide a sinusoidal acceleration of 1 g peak at 79.6 Hz ($\omega = 500$).

1. Carry out the preliminary adjustments if necessary.

Accelerometer Sensitivity mV/g	B & K Accelerometer Type	Scale No.
1.7– 6	4344 8303 4345	SA 0142
6 – 17	4339 4343 8301 8302 4333 4335 4340	SA 0058
17 – 60	4332 4334	SA 0143
60 –170	4338	SA 0144

Table 3.2. Accelerometer scales for use with the 2010

2. Fit the meter scale appropriate to the sensitivity of the accelerometer being used. (See Table 3.2).

3. Plug the accelerometer and associated preamplifier into the appropriate input on the 2010.

4. Set the controls as follows:

GAIN CONTROL	"Cal."
OUTPUT SECTION ATTENUATOR	"x 1"
EFFECTIVE AVERAGING TIME	"Fast"
READ OUT SELECTOR	"Lin." AC or DC
FREQUENCY RESPONSE	"Linear"
INPUT	As appropriate

5. Set the INPUT SECTION ATTENUATOR so that a full scale deflection of 1 g is indicated on the range setting indicators.

6. Using the Accelerometer Calibrator vibrate the accelerometer at 1 g peak.

7. Adjust the SENS. potentiometer beside the appropriate input socket until a deflection of 0.707 g RMS is obtained. (0.707 g RMS = 1 g peak).

Using Internal Reference Voltage

1. Carry out the preliminary adjustments if necessary.

2. Fit the meter scale appropriate to the sensitivity of the accelerometer being used. (See Table 3.2).

3. Plug the accelerometer and associated preamplifier into the appropriate input on the 2010.

4. Set the controls as follows:

GAIN CONTROL	"Cal."
OUTPUT ATTENUATOR	"x 1"
EFFECTIVE AVERAGING TIME	"Fast"
READ OUT SELECTOR	"Lin.", AC or DC
INPUT	As appropriate

FREQUENCY RESPONSE "Linear"

Depress REF. 50 mV push-button.

5. From the calibration chart of the accelerometer, calculate the acceleration level which corresponds to a voltage output from the preamplifier of 50 mV RMS. For example, if a B & K Type 4343 Accelerometer of sensitivity 10.1 pC/g is used with a Type 2624 Charge Amplifier with a gain setting of 1 mV/pC, then a voltage level of 50 mV RMS is produced by a signal of 4.95 g RMS.

6. Set the INPUT SECTION ATTENUATOR so that the acceleration level calculated in point 5 will appear on-scale. For the example given, the meter scale indication should be set for a full scale deflection of 10 g.

7. Adjust the SENS. potentiometer beside the input socket in use so that the acceleration level calculated in point 5 is correctly indicated on the meter.

3.2.4. Insert Voltage Calibration

When the Type 2627 Preamplifier is used in conjunction with the 2010, 1 inch microphones can be calibrated by means of the Insert Voltage or substitution method. This is a method for determining the open circuit sensitivity of the microphone. The open circuit voltage of a microphone is defined as the voltage at a single given frequency which appears at its terminals when the microphone is working into an infinite electrical impedance.

This open circuit voltage can be determined by the insert voltage technique even when the microphone is terminated in a *finite* electrical impedance, such as the input impedance of an amplifier. The principle of the method may be explained with reference to Fig.3.2.

The condenser microphone, capacitance C_M, is first subjected to a known sound pressure level, (position "a" on the figure). The open circuit voltage produced is E_o, and the voltage at the input to the amplifier is V. The sound source is then stopped. However, for the validity of this method, the microphone should be terminated in the same acoustical impedance. Therefore any couplers, etc. used to connect the sound source to the microphone, should not be removed.

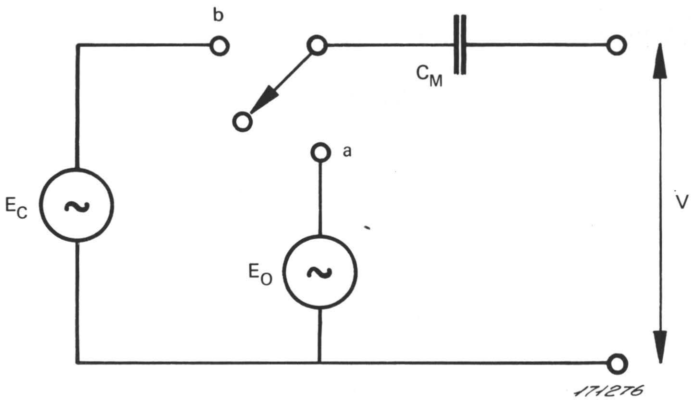

Fig.3.2. Insert Voltage Calibration of a Microphone

A source of known and adjustable voltage, E_c, is then connected in series with the microphone (position"b" on the figure). This insert voltage is adjusted until the input voltage to the amplifier is the same (V) again. Then $E_o = E_c$ and the open circuit voltage sensitivity can be calculated as follows:

$$\text{Open Circuit Voltage Sensitivity} = \frac{E_c}{\text{sound pressure}}$$

When the 2627 is used with the 2010 the insert voltage E_c can be supplied in two ways. The internal reference oscillator can be used to give a voltage at a fixed frequency of 1 kHz, or the B.F.O. section of the 2010, or an external generator, can be used to give a signal at any other required frequency.

It is also necessary to have a sound source of known pressure level and frequency. This can be provided in two convenient ways:

a) The B & K Sound Level Calibrator Type 4230 produces a signal at 1 kHz, 94 dB SPL, and may be used when the insert voltage is supplied by either the internal reference oscillator, or by the B.F.O. section, or by an external generator.

b) The B & K Pistonphone Type 4220 produces a signal at 250 Hz, 124 dB SPL, and may be used when the insert voltage is supplied by the B.F.O. section or by an external generator. Using the normal voltage scale supplied with the 2010 (SA 0051), recommended procedures are as follows:

Using the internal reference oscillator facility

1. Fit the microphone to the 2627 Preamplifier and connect to the PREAMP. input of the 2010.

2. Set the controls as follows:

GAIN CONTROL	"Cal."
OUTPUT SECTION ATTENUATOR	"x 1"
INPUT SECTION ATTENUATOR	"100 mV"
EFFECTIVE AVERAGING TIME	"Fast"
READ OUT SELECTOR	"Lin.", AC or DC
FREQUENCY RESPONSE	"Linear"
INPUT	"Preamp."

3. Fit the Sound Level Calibrator 4230 on to the microphone and press the calibrator button. Note the voltage V indicated on the meter scale.

4. Wait till the Sound Level Calibrator switches itself off, but do not remove it from the microphone. This to ensure the microphone is terminated in the same acoustical impedance. Then depress the INSERT VOLT. CAL. "Int." push-button on the 2010. Then adjust the GAIN CONTROL until the voltage V is the same as before.

5. Then, the calibration voltage from the reference oscillator is equivalent to the open circuit voltage E_o of the microphone. This calibration voltage E_c can be measured by depressing the "Ref. 50 mV" push-button and reading the meter *without* adjusting the GAIN CONTROL.

Then:

$$\text{Open Circuit Voltage Sensitivity} = \frac{E_c}{\text{Sound Pressure}}$$

In this case, the sound pressure produced by the Sound Level Calibrator is 94 dB SPL = 1 N/m^2.

Note: When point 5 is carried out, the change in voltage indicated on the meter will be very small (within 0.2 dB). This is because of the very low attenuation due to the preamplifier.

Using B.F.O. section or an external generator

1. Connect the generator output to the EXT. INSERT VOLTAGE socket on the rear panel of the 2010.

2. Fit the microphone to the 2627 preamplifier and connect to the PREAMP. input of the 2010.

3. Apply the sound source to the microphone: If the Pistonphone Type 4220 is used, this involves fitting the Pistonphone onto the microphone and moving the switch to the "Measure" position. Note the voltage V indicated on the meter of the 2010.

4. Switch the Pistonphone off, but leave the Pistonphone mounted on the microphone to ensure that the microphone is terminated in the same acoustical impedance.

   Adjust the frequency of the generator to be the same as that of the sound source. Depress the push-button INSERT VOLT. CAL. "Ext." and adjust the output of the generator until the voltage V indicated is the same as before.

5. Then the calibration voltage from the generator is equivalent to the open circuit voltage E_o of the microphone. This calibration voltage, E_c, can be measured by taking a lead from the output of the generator to the DIRECT input of the 2010. The calibration voltage then can be read directly on the meter scale by depressing the "Direct" INPUT and CAL. OFF push-buttons.

   The output from the generator should be terminated in the EXT. INSERT VOLTAGE socket on the rear panel of the instrument while the calibrating voltage is being read from the meter.

Again:

$$\text{Open Circuit Voltage Sensitivity} = \frac{E_c}{\text{Sound Pressure}}$$

N.B.

a) If the Type 4220 Pistonphone is used it produces a sound pressure level of approx. 124 dB = 31.6 N/m^2. The generator frequency should be adjusted to 250 Hz.

b) If the Sound Level Calibrator is used it produces a sound pressure level of approx. 94 dB = 1 N/m^2. The generator frequency should be adjusted to 1 kHz.

4. OPERATION

4.1. VOLTAGE MEASUREMENTS

4.1.1. Input Voltages up to 300 Volts RMS

1. Calibrate the 2010 as described in section 3.2.1.

2. Set the controls as follows:

GAIN CONTROL	"Cal."
INPUT SECTION ATTENUATOR	"300 V"
OUTPUT SECTION ATTENUATOR	"x 1"
EFFECTIVE AVERAGING TIME	"Fast" or as appropriate for analysis
READ OUT SELECTOR	As appropriate to scale used and output required
FREQUENCY RESPONSE	"Linear"
INPUT push-button	As appropriate

3. Feed the unknown voltage to the input used, and adjust the INPUT SECTION ATTENUATOR until a suitable deflection is obtained. If the deflection is insufficient, even when the INPUT SECTION ATTENUATOR is in its "10 mV" position, then adjust the OUTPUT SECTION ATTENUATOR.

4.1.2. Input Voltages up to 700 Volts Peak

Use can be made of the GAIN CONTROL to accommodate input voltages of up to 700 Volts peak. However the 2010 must be calibrated to give exactly 10 dB attenuation. Procedure is as follows:

1. Repeat the calibration procedure, as described in section 3.2.1.

2. With the meter scale pointer set on the red mark (50 mV) set the INPUT SECTION ATTENUATOR to 30 mV causing the needle to deflect off scale.

3. Adjust the GAIN CONTROL to bring the needle back to the red mark. The 2010 is then calibrated so that 10 dB must be added to the value of all meter indications.

4.2. SOUND MEASUREMENTS

1. Calibrate the 2010 and the microphone as described in section 3.2.2.

2. Hold the microphone steadily and at least 1 meter away from the body, or set it up on a tripod or any other support that will not interfere with the sound field.

3. Depress the "Selective" FREQUENCY RESPONSE push-button, then select the appropriate weighting network (A, B, C, D or Lin.) as required by switching the frequency scale pointer.

4. With the OUTPUT SECTION ATTENUATOR in the "x1" position adjust the INPUT SECTION ATTENUATOR until a suitable meter deflection is obtained without any indicated overload. If the deflection is insufficient, even when the INPUT SECTION ATTENUATOR is in its "10 mV" range, then adjust the OUTPUT SECTION ATTENUATOR.

   If the INPUT OVERLOAD light flashes, turn the INPUT SECTION ATTENUATOR to a higher range.

   If the OUTPUT OVERLOAD light flashes, turn the OUTPUT SECTION ATTENUATOR to a higher range.

5. The measured Sound Level or Sound Pressure Level is the sum of the meter reading and the attenuator setting displayed by the range setting indicators.

   The weighting network used should always be stated when reporting results, e.g. 60 dB (A), 60 dB (D), etc.

For further information on sound measurements the B & K booklet, "Acoustic Noise Measurements" is available on request.

4.3. VIBRATION MEASUREMENTS

1. Calibrate the 2010 and the accelerometer as described in section 3.2.3.

2. Mount the accelerometer on the measurement object (for recommended methods, see the accelerometer instruction manual).

3. Keep the 2010 as far away as possible from the vibration environment and any other unwanted influences.

4. With the OUTPUT SECTION ATTENUATOR in "x 1" position, adjust the INPUT SECTION ATTENUATOR until a suitable deflection is obtained without any indicated overload. If the deflection is insufficient, even when the INPUT SECTION ATTENUATOR is in its 10 mV range, then adjust the OUTPUT SECTION ATTENUATOR.

   If the INPUT OVERLOAD light flashes, turn the INPUT SECTION ATTENUATOR switch to a higher range.

   If the OUTPUT OVERLOAD light flashes, turn the OUTPUT SECTION ATTENUATOR switch to a higher range.

5. For further information on vibration measurement the B & K booklet "Mechanical Vibration and Shock Measurements" is available on request.

4.4. SELECTIVE MEASUREMENTS

For selective sound, vibration or voltage measurements between 2 Hz and 200 kHz using a selected bandwidth and effective averaging time, the procedure is as follows:

1. Carry out the appropriate calibration procedure as described in section 3.2.

2. Connect the appropriate transducer and preamplifier to the 2010.

3. Set the controls as follows:

FREQUENCY RESPONSE	"Selective"
SELECTIVITY CONTROL	As required
EFFECTIVE AVERAGING TIME	As required
B & T PROGRAM	"Manual"
OUTPUT SECTION ATTENUATOR	"x 1"
BANDWIDTH COMP.	- if necessary
GAIN CONTROL	"Cal."

4. Turn the frequency scale pointer to the frequency of interest, and set the frequency range switch accordingly. If necessary, fine tuning can be carried out using the FREQUENCY INCREMENT knob.

5. Adjust the INPUT SECTION ATTENUATOR until a suitable deflection is obtained without any indicated overload. If the deflection is insufficient, even when the INPUT SECTION ATTENUATOR is in its 10 mV range, then adjust the OUTPUT SECTION ATTENUATOR.

   If the INPUT OVERLOAD light flashes, turn the INPUT SECTION ATTENUATOR switch to a higher range.

   If the OUTPUT OVERLOAD light flashes, turn the OUTPUT SECTION ATTENUATOR switch to a higher range.

4.5. USE OF THE B.F.O. SECTION

The B.F.O. section may be used with or without the regulation (compression) circuit. If the compression circuit is not required, the COMPRESSOR SPEED selector should be in the "Off" position.

The output voltage (or the generated e.m.f.) from the generator may be indicated on the meter scale of the 2010 by depressing the push-button marked METER AND RECORDER, "B.F.O.". The full scale deflection is fixed by the B.F.O. ATTENUATOR switch, and the output level is varied using the B.F.O. OUTPUT VOLTAGE knob.

Note: Adjustment of the INPUT and OUTPUT SECTION ATTENUATOR of the Measuring Amplifier section does not affect the B.F.O. output.

If the compression circuit is used, the feedback signal is fed into the COMPRESSOR INPUT socket.

To regulate the B.F.O. output signal the procedure is as follows:

1. Turn the COMPRESSOR VOLTAGE knob fully clockwise.

2. Turn the B.F.O. OUTPUT VOLTAGE knob fully anticlockwise.

3. Connect the feedback signal, which must be of a sufficiently high level (at least 0.5 Volts) to the COMPRESSOR INPUT.

4. Select a suitable regulation speed using the COMPRESSOR SPEED switch.

5. Turn the B.F.O. OUTPUT VOLTAGE knob *slowly* clockwise to the maximum position, checking that the compressor circuit works.

6. Turn the COMPRESSOR VOLTAGE knob anticlockwise until the desired level is obtained.

4.6. REMOTE CONTROL OF THE 2010

4.6.1. Frequency Control

1. Select the position "Ext. Volt." on the SWEEP CONTROL.

2. The DC control voltage (between 0 and 10 Volts) is applied to pins 6 and 7 of the FREQUENCY CONTROL VOLTAGE "In" socket, see Fig.4.1.

3. The remaining controls on the 2010 are selected appropriate to the measurement being made.

Note: If a B & T programme is not used, the B & T PROGRAM Selector should be in the "Manual" position, and the frequency scale pointer should be in the passive zone.

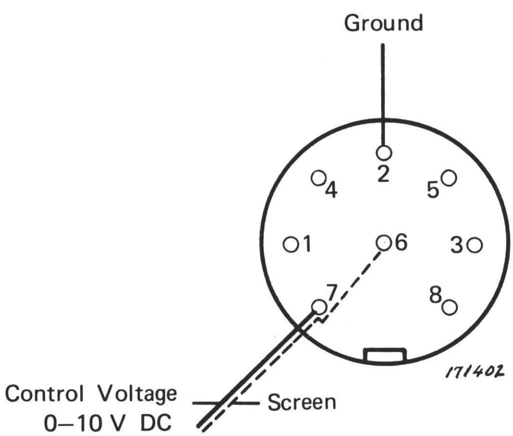

Fig.4.1. Connection for remote control of frequency by a D.C. Voltage

4.6.2. B & T Programmes

Remote control of a B & T programme is only possible when the frequency control voltage itself is provided by an external voltage. In this case, the procedure is as follows:

1. The frequency is controlled according to section 4.6.1.

2. Position the frequency scale pointer in the passive zone.

3. Choose a suitable programme using the three selectors B & T PROGRAM, SELECTIVITY CONTROL, and EFFECTIVE AVERAGING TIME. See Tables 5.1 to 5.4.

4. Using the B & T Remote Control socket (EXT. B & T PROGRAM) on the rear panel, ground the pin appropriate to the desired range. See Section 5.3.5.

5. DESCRIPTION

5.1. GENERAL

An overall block diagram of the Heterodyne Analyzer Type 2010, considerably simplified, is shown in Fig.5.1, while more detailed block diagrams for the different sections are shown in Figs.5.2, 5.3, 5.7, and 5.10.

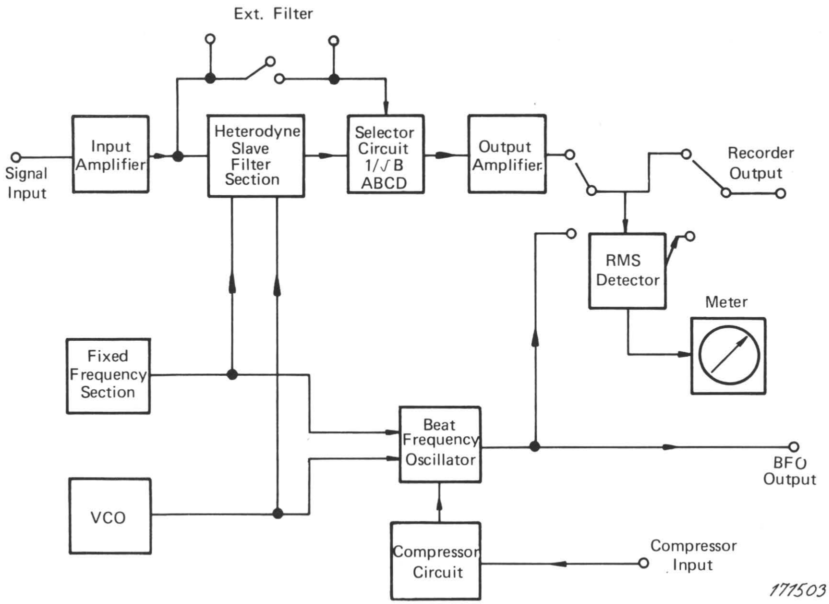

Fig.5.1. Simplified Block Diagram of 2010

The signal for analysis enters the analyzer at the input (either DIRECT or PREAMP. input), and is fed to the first mixer stage via the input attenuator and amplifier. In this first stage it is mixed with the signal from the voltage controlled oscillator (V.C.O.). The V.C.O. has a frequency which is adjustable in the range 1.0 MHz to 1.2 MHz in order to produce a 1.2 MHz signal after mixing with the frequency of interest in the input signal. The new signal is then fed into the second mixer via a 1.2 MHz band pass filter. The centre frequency of the signal is transformed to 30 kHz at the second mixer by mixing with a 1.23 MHz signal. The resulting 30 kHz signal is fed to the 30 kHz centre frequency band pass filter where the 1000 Hz and 316 Hz bandwidths of the input signal are obtained. From this stage the signal is fed to the selector circuit.

If a bandwidth in the range 3.16 to 100 Hz is required, the signal from the 1.2 MHz band pass filter is fed to the third mixer. In the third mixer, the signal frequency is transformed to 750 Hz, by mixing with a 30.75 kHz signal from the fixed frequency section. The 750 Hz signal is fed to the 750 Hz centre frequency band pass filter where the selected bandwidth is obtained.

The signal from this final mixer is then fed to the output section via the selector circuit.

The selector circuit feeds the output section amplifier with either: the filtered signal from the second or third mixer, with or without bandwidth compensation, or: the signal issued from the input section amplifier, conditioned by the internal linear or standard ABCD weighting networks or by an external filter.

The signal from the output amplifier is fed to the RMS rectifier, where the averaging time can be selected. The level of the signal is indicated on the meter scale. The signal is also present at the recorder output. The read-out selector offers the choice of AC, linear or logarithmic DC signals.

The analyzer section and the beat frequency oscillator (B.F.O.) section are supplied by the same voltage controlled oscillator (V.C.O.). The signal from the V.C.O. which is fed to the first mixer is also fed to the B.F.O. where it is mixed with a 1.2 MHz signal to give a sinusoidal output of frequency corresponding exactly to the tuning frequency of the analyzer.

The level of the B.F.O. signal can be regulated by means of the compressor circuit.

5.2. AMPLIFIER SECTION

5.2.1. Input Section

A block diagram of the input section is shown in Fig.5.2.

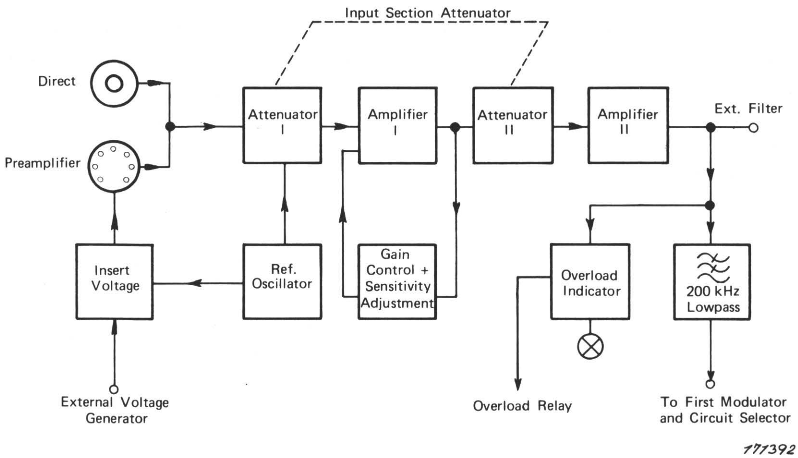

Fig.5.2. Input section block diagram

The input section has two alternative input sockets. The DIRECT INPUT socket is a standard B & K input socket and accepts the B & K plug type JP 0101. The input impedance of the DIRECT INPUT is 1 MΩ//80 pF. The PREAMP. INPUT is a standard 7 pin microphone input socket which provides all the necessary power supplies for B & K microphone preamplifiers and condenser microphones. This socket accepts the B & K 7 pin plug JP 0701. The input impedance of the PREAMP. INPUT is 900 kΩ//180 pF.

Both inputs lead to the INPUT SECTION ATTENUATOR which is divided into two sections in order to obtain the best signal-to-noise ratio in all switch positions. The attenuator steps down the input signal in accurate 10 dB steps up to a maximum attenuation of 90 dB. This enables a maximum input voltage of 300 V RMS to be measured in the calibrated mode.

However, if the extra attenuation of the GAIN CONTROL is also used, input voltages up to 700 V peak can be measured. When the GAIN CONTROL is moved from its "Cal." position, the total attenuation is not a specific number of 10 dB steps, and a small indicator lamp is lit indicating this uncalibrated mode.

The input amplifier, similarly, is divided into two sections with an attenuator section in between. This ensures the best overall signal-to-noise ratio. The first amplifier section contains a balanced input stage to regulate the sensitivity of the two input sockets. The two SENS. potentiometers and the

GAIN CONTROL potentiometer together have an attenuation range between 0 and 21 dB. The gain of the second amplifier section is fixed at 19 dB. Hence, the overall gain of the input amplifier stage is 40 dB maximum. The output impedance of this stage is 10 Ω.

From the input amplifier the signal is fed either to an external filter (EXT. FILTER sockets) or to an internal low pass filter which eliminates frequencies above 200 kHz.

Overload Indicators

An overload of the input amplifier which would introduce distortion into the signal, may not always be noticed, especially if the output amplifier itself is not overloaded. Also this overload may be caused by frequencies which may not be present after filtering or weighting. Therefore, an overload indicator is placed at the output of the first amplifier. If the peak voltage exceeds a certain value (5.0 V) at the output of this amplifier, the overload lamp will light for at least 0.5 secs, even though the overload condition may be as short as 200 μsecs.

The input overload indicator and the output overload indicator are connected in parallel to a relay which can be used, for example, to operate a marker pen on the B & K Level Recorder Type 2305. The output of this relay is available at the OVERLOAD and FREQUENCY MARKING socket on the rear panel of the instrument. The screwdriver operated switch at the side of this socket should be in position "Overload".

Reference Oscillator

A reference oscillator is incorporated in the 2010 for calibration purposes. The oscillator is operated by the push-button "Ref. 50 mV". It produces an accurate 50 mV sinusoidal voltage at 1000 Hz. The amplitude stability, frequency stability and distortion are better than 2%. A frequency of 1 kHz was chosen since the weighting networks have no attenuation at this frequency.

The signal from the input section is either filtered, internally or externally, or carried directly to the output section of the measuring amplifier.

5.2.2. Output Section

A block diagram of the output section is shown is Fig.5.3.

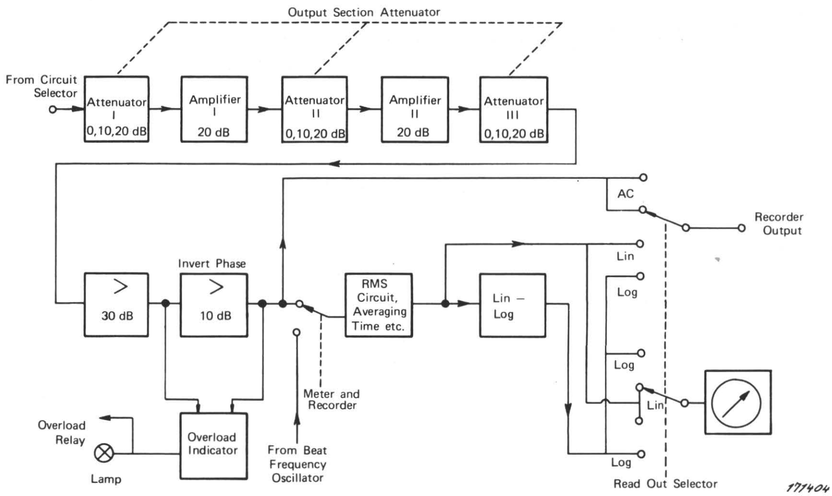

Fig.5.3. Output section block diagram

The output section is split into several stages in order to obtain the best possible signal-to-noise ratio. The attenuator is split into three sections, each with an attenuation of 0, 10 or 20 dB. This gives a total attenuation of 60 dB in 10 dB steps. Situated between the attenuators are two amplifiers, each providing 20 dB gain.

The final amplifier stage separates the signal into two components. The component which is in phase with the input signal is amplified by 30 dB. The anti-phase component is amplified by 40 dB. This component is then fed to the RMS detector.

Output Overload Indicator

An overload indicator is placed at the amplifier output in order to safeguard against signals of too high a peak value. It is driven by the two output signal components, i.e. in-phase and anti-phase components. It is also connected in parallel with the input overload indicator to the overload relay.

5.2.3. RMS Detection and Averaging

Circuits for extracting the RMS value of an alternating signal consist in principle of squaring, averaging, and root extracting sections, as illustrated in Fig.5.4.a. The Brüel & Kjær RMS detectors, however, modify this general principle by feeding back the voltage on the averaging capacitor to produce a "variable squaring" characteristic, as in Fig.5.4b, removing the necessity for a separate square root operation. The principle of the circuit and its difference from conventional RMS detectors is discussed in the Brüel & Kjær Technical Review, 1969 No. 1 ("Impulse Noise Measurements" by C.G. Wahrmann). The effective averaging time of the RMS circuit is approximately equal to the RC time constant of the detector.

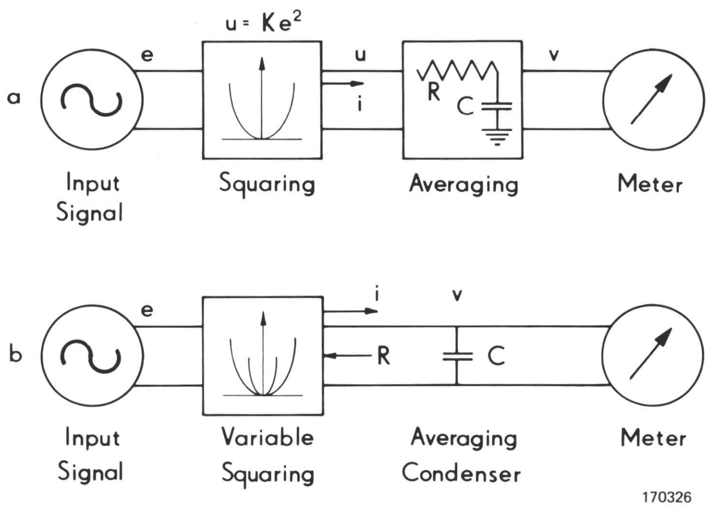

Fig.5.4. Principles of R.M.S. Rectifier Circuit

A schematic diagram to illustrate the principle of the RMS detector of the 2010 is shown in Fig.5.5. At the input of the detector the inverted AC signal from the Output Section is amplified by 20 dB and split into two components, one in phase with the Output Section signal and the other 180° out of phase. These two signals are then applied to the two rectifying diodes D_1 and D_2 of the RMS Rectifier (Fig.5.5) which are biased off by a voltage on the averaging capacitor C_A. When the instantaneous signal level at either of the rectifier inputs exceeds the level of the averaging capacitor bias, the diode D_1 or D_2 will conduct. If the instantaneous signal level is increased further, the rectifier current will rise linearly to charge the averaging capacitor via the resistor R_1 and to raise the voltage levels at the junctions of the resistance chain. $R_{5\text{-}8}$. The resistance chain determines the

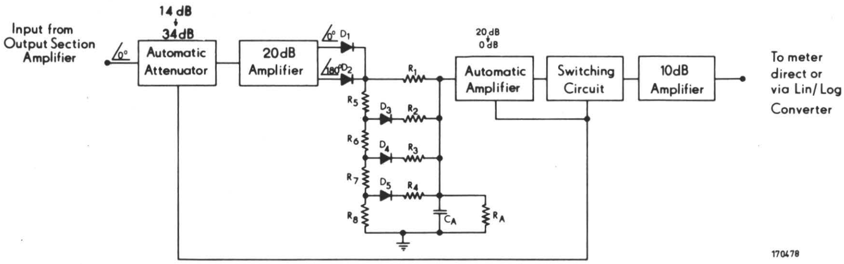

Fig.5.5. Schematic of R.M.S. Rectifier Circuit

instantaneous signal level for which the diodes $D_{3\text{-}5}$ will conduct. As each diode conducts, the value of the averaging capacitor's charging resistance, set by $R_{1\text{-}4}$, is reduced, causing the slope of the rectifier current v. instantaneous input voltage curve to increase. The magnitude of the resistors is selected to form a parabola, which is the characteristic required from the squaring circuit. Fig.5.6 illustrates this principle. As the diodes $D_{3\text{-}5}$ switch in parallel resistors, so the slope of the inclined line will be increased in a series of limbs to improve the approximation to the ideal parabola at high instantaneous values of the input voltage, e. The three diodes provide a total of five limbs on the parabola approximation, permitting the detector to measure signals with crest factors up to 5 with an accuracy of $\pm$ 0.5 dB.

As the charge on the averaging capacitor varies so does the voltage across the averaging capacitor. This alters the bias applied to the diodes, resulting in a displacement of the RMS Rectifier's characteristic. The whole effect is equivalent to a multiplication of the parabola's size by a constant factor equal to that by which the charge on the averaging capacitor was changed. From Fig.5.6 it can be seen that this corresponds to a root extraction process, as the charging current is now proportional to the input voltage. Consequently the RMS circuit's output will be linear even though the RMS Rectifier's instantaneous voltage characteristic is a parabola.

At the same time as the averaging capacitor C_A is charged a discharge current proportional to the voltage across the averaging capacitor flows through the averaging resistor R_A. Therefore if the voltage on the averaging capacitor remains constant for a period of time equal to or exceeding the time constant of the averaging network (C_A in parallel with R_A) the charging current is proportional to the RMS value of the input voltage.

The averaging circuit of the 2010 is rather more complex than the

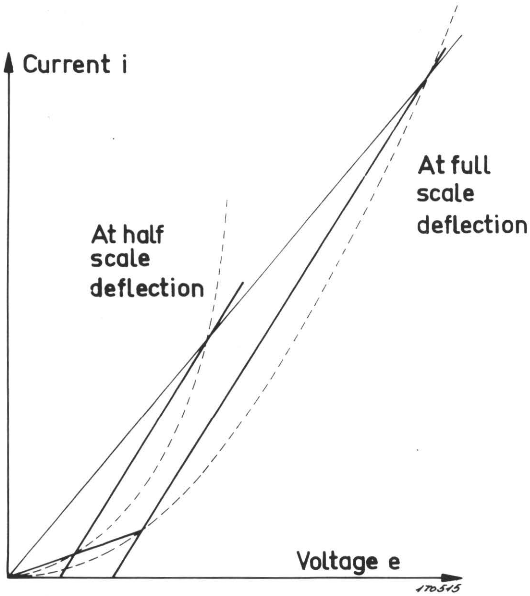

Fig.5.6. Current – Voltage characteristic of R.M.S. detector

schematic (Fig.5.5) implies, since it is in fact made up of a number of averaging networks which give averaging times ranging from 0.1 to 100 secs. and includes time constants which give "Fast" and "Slow" meter response characteristics.

The averaging capacitors in the RMS Rectifier of the 2010 are all interconnected using FET gates which may be controlled from either the B & T programmes or the EFFECTIVE AVERAGING TIME switch of the 2010. This permits automatic as well as manual selection of averaging times. The gates allow all the averaging capacitors in the circuits to charge to the level of the RC network selected. This does not alter the averaging time of the selected network, but does prevent it from discharging unnecessarily and producing a temporarily inaccurate output or meter reading when a longer averaging time is selected.

To obtain the widest possible dynamic range for the RMS Rectifier, two attenuators are employed in the RMS circuit. These are operated automatically via a Switching Circuit which is triggered when the signal level is higher than that corresponding to 20 dB below FSD (Full Scale Deflection).

When triggered, the attenuators effectively attenuate the signal level at the input to the RMS Rectifier by 20 dB and boost its output by an equal amount. The attenuators are automatically reset by the Switching Circuit when the meter indication falls to 25 dB below FSD. The 5 dB difference between the Switching Circuit triggering levels removes the possibility of signal ripple causing the dynamic range to be extended accidentally. The overall RMS circuit gain is therefore not changed, but the dynamic range is, and is extended to 50 dB.

The linear DC output from the RMS Rectifier which is now proportional to the RMS value of the signal applied to the 2010 is amplified 10 dB by the final stage of the RMS circuit and passed to the display meter, either directly or via the Lin/Log converter. The RMS value can be read directly from the meter when it is used with any one of the appropriate Lin or Log scales supplied with the 2010.

5.3. ANALYZER SECTION

The block diagram of the analyzer and oscillator section is shown in Fig.5.7. The analyzer section is driven by the two oscillators of the BFO section:

a) a fixed frequency crystal oscillator, connected to frequency converters which provide all the fixed frequencies necessary, and

b) a voltage controlled oscillator (V.C.O.) which provides the variable frequency.

5.3.1. Fixed Frequency Oscillator

The fixed frequency oscillator is a quartz crystal parallel resonance type oscillator which generates approximately 1 Volt peak-to-peak at a frequency of 960 kHz.

The signal then is processed by frequency converters which produce the following frequency outputs:

f_o = 1.20 MHz for the B.F.O. and an external output
f_1 = 1.23 MHz for the second mixer and the V.C.O. stabilization
f_2 = 30.75 kHz for the 3rd mixer

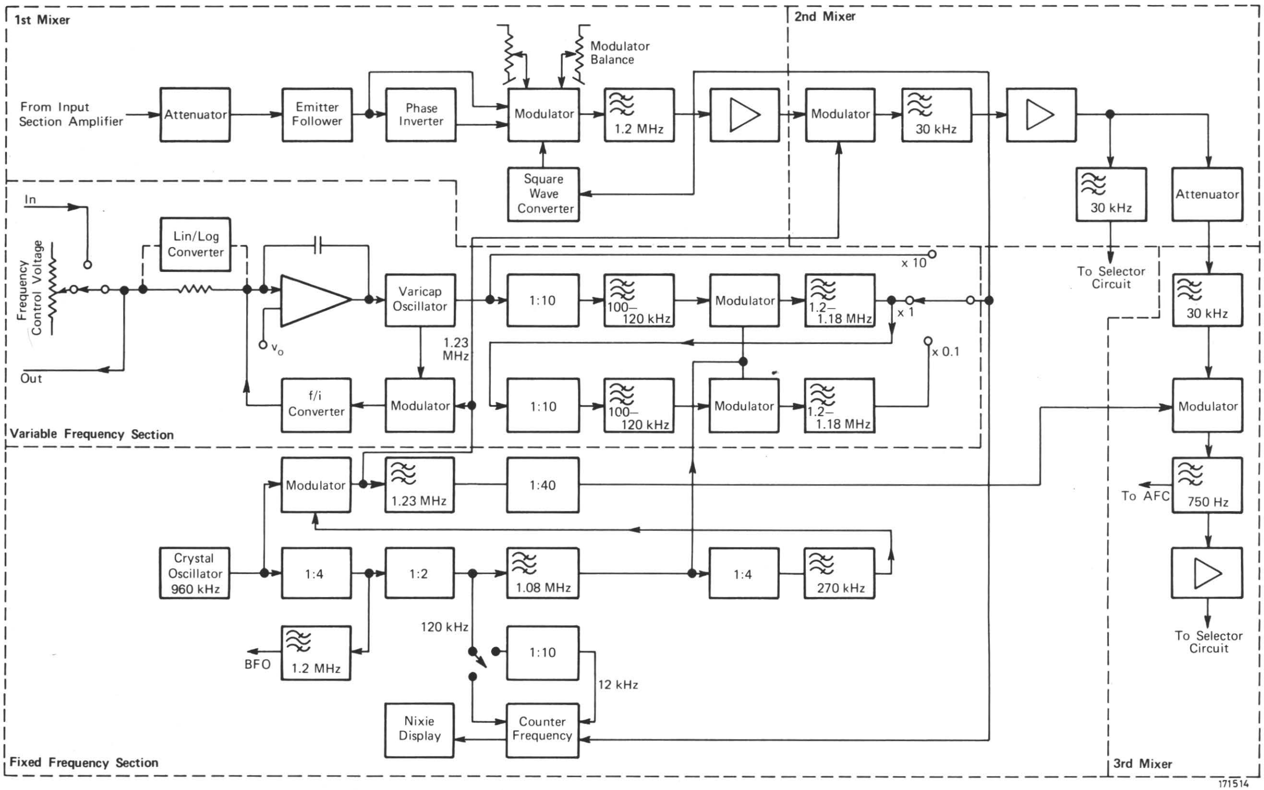

Fig.5.7. Analyzer Section block diagram

f_3 =	1.08 MHz	for the V.C.O. frequency converter
f_4 =	120 kHz	for the frequency counter and 2020 output
f_5 =	12 kHz	for the frequency counter

5.3.2. Voltage Controlled Oscillator (V.C.O.)

The controlling DC voltage for the V.C.O. can be supplied in two ways,

a) from a potentiometer mechanically connected to the shaft in the centre of the frequency scale, or

b) from an external voltage source.

The DC voltage signal is either fed directly to the oscillator circuit giving a linear sweep or via a linear to logarithmic converter resulting in a logarithmic sweep. The output from the V.C.O. covers the range 1.2 MHz to 1.0 MHz (linear). This produces a frequency range of 0 to 200 kHz. However in order to provide the necessary frequency resolution and low frequency stability, the V.C.O. output is fed to two converters which each decrease the frequency range of the instrument by one decade. The first converter transforms the V.C.O. range to 1.2 MHz to 1.18 MHz (frequency tuning range 0 to 20 kHz) and the second transforms to 1.2 MHz to 1.198 MHz (frequency tuning range 0 to 2 kHz). The same relative stability, therefore, is obtained in all the ranges.

Note: When a varying DC control voltage is applied, there will be a delay on the frequency change of the output signal corresponding to 1.50 msec.

If for instance the regulation voltage changes at a rate corresponding to 100 Hz/sec. the signal frequency will be $1.50 \times 10^{-3} \times 100 = 0.150$ Hz "behind". The settling down time of the VCO is 30 msec.

5.3.3. Frequency Counting and Marking

The tuned-in frequency of the analyzer is periodically sampled and shown on a 6 digit Nixie display. The sampling time is 0.1 seconds. which may increased to 1 second by depressing the COUNTING TIME INCREASE push-button. The longer sampling time gives an extra digit resolution on the display.

If the frequency marking facility is used, the change in value of a preselected digit (3rd, 4th or 5th digit from the left) can be recorded using the event marker pen on the B & K Level Recorder Type 2305 or 2307. The digit which operates the marker relay is selected by a screwdriver operated switch situated on the rear panel. The cable (AQ 0027) for connection of the frequency marking socket on the 2010 and the event marker socket on the Level Recorder Type 2305 is supplied with the 2010.

The cable (AQ 0035) for connection of the frequency marking socket on the 2010 and the event marker socket on the Type 2307 is not supplied, but is available upon request.

A short pulse is supplied to the event marker pen every time the selected digit changes. When the selected digit becomes zero, a continous signal is provided to the marker pen until the digit changes again.

5.3.4. Mixer Section

1st Mixer

The input signal, f_s, is mixed with a signal f_v from the voltage controlled oscillator. If the tuned frequency of the analyzer is f_s, the frequency of the V.C.O. is:

$$f_v = f_o - f_s$$

Where f_o is a fixed frequency of 1.2 MHz. Hence the signal emerging from the first mixer is always of frequency 1.2 MHz. The modulator is balanced in order to suppress the frequency f_v which may be present, in the resulting signal. Instructions for balancing the modulator may be found in section 3.1.3. The modulator is followed by a bandpass filter in order to suppress the image frequency of 1.26 MHz signal which may be present. This frequency if mixed with the 1.23 MHz signal may produce an unwanted 30 kHz signal. The band pass filter suppresses the 1.26 MHz signal by at least 85 dB.

2nd Mixer

The signal from the first mixer is fed into a balanced modulator which also receives a 1.23 MHz signal from the fixed frequency section. A signal of centre frequency 30 kHz is produced together with some unwanted high frequency components. The high frequency components are removed by a double 2 pole Butterworth band pass filter. The two parts of the filter are separated by an amplifier section. The 1000 Hz and 316 Hz analysis bandwidths are selected in this section. The sensitivity of the filter may be adjusted by potentiometers (FILTER SENSITIVITY ADJUSTMENTS) situated on the rear panel, see Preliminary Adjustments and Calibration, section 3.1.4.

3rd Mixer

The output from the second mixer is fed into another band pass filter, centre frequency 30 kHz, which further suppresses the image frequency of 31.5 kHz. From the filter the output signal is fed into a balanced modulator

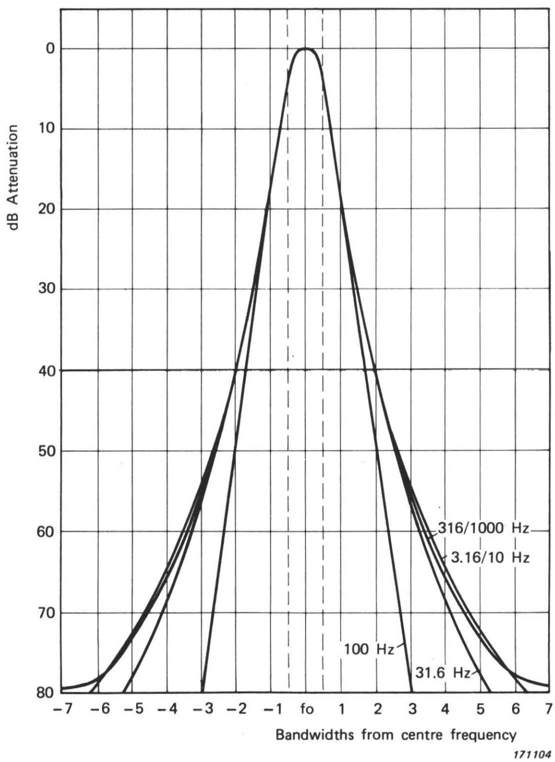

Fig.5.8. Typical filter characteristics

which also receives a 30.75 kHz signal from the fixed frequency section. A signal of frequency 750 Hz is produced, which is filtered with one of the following bandwidths, 3.16, 10, 31.6 and 100 Hz at a centre frequency of 750 Hz, thus removing any high frequency component and providing the required analysis level. The pass band levels of these filters may be adjusted using the potentiometers (FILTER SENSITIVITY ADJUSTMENTS) situated on the rear panel, see section 3.1.4. Typical overall filter characteristics are shown in Fig.5.8.

5.3.5. B & T Programmes

The B & T Programmes permit the selection of the most suitable bandwidth and effective averaging time for given frequencies or frequency ranges in order to obtain optimized measuring conditions. In certain cases the selection of a suitable B & T programme can decrease the measuring time considerably, see Appendix section 9.2.

The B & T programme selector (B & T PROGRAM) has five positions. The position "Manual" enables a fixed bandwidth and averaging time to be selected, as indicated on the SELECTIVITY CONTROL and EFFECTIVE AVERAGING TIME switches.

In the other positions, the bandwidth and/or the averaging time are not only dependent on the bandwidth and averaging time switch positions, but also on the frequency pointer position. The different bandwidth and averaging time combinations and the switching frequencies are given in Tables 5.1 to 5.4.

SELECTIVITY CONTROL POSITION	Automatically selected bandwidth (Hz)					
1000 Hz	3.16	10	31.6	100	316	1000
316 Hz	3.16	3.16	10	31.6	100	316
100 Hz	3.16	3.16	3.16	10	31.6	100
31.6 Hz	3.16	3.16	3.16	3.16	10	31.6
10 Hz	3.16	3.16	3.16	3.16	3.16	10
3.16 Hz	3.16	3.16	3.16	3.16	3.16	3.16
Switch-over Frequency Hz (x1, log scale)	63	200	630	2K	6.3K	

Switch-over frequencies x0.1, x1, x10 according to range.

Table 5.1. Selected bandwidth with B & T PROGRAM selector in position "B. Var. 1". T is as selected on the EFFECTIVE AVERAGING TIME switch

EFFECTIVE AVERAGING TIME selected	Automatically selected averaging time (sec.)					
0.1 sec	30	10	3	1	0.3	0.1
0.3 sec	100	30	10	3	1	0.3
1 sec	100	100	30	10	3	1
3 sec	100	100	100	30	10	3
10 sec	100	100	100	100	30	10
30 sec	100	100	100	100	100	30
100 sec	100	100	100	100	100	100
Switch-over Frequency Hz (x1, log scale)	63 200 630 2K 6.3K					

Switch-over frequencies x0.1, x1, and x10 according to range.

Table 5.2. Selected EFFECTIVE AVERAGING TIME with B & T PROGRAM selector in position "T. Var. 2". Bandwidth, B, is as selected on the SELECTIVITY CONTROL

SELECTIVITY CONTROL position	Automatically selected bandwidth (Hz)			
1000 Hz	31.6	100	316	1000
316 Hz	10	31.6	100	316
100 Hz	3.16	10	31.6	100
31.6 Hz	3.16	3.16	10	31.6
10 Hz	3.16	3.16	3.16	10
3.16 Hz	3.16	3.16	3.16	3.16
EFFECTIVE AVERAGING TIME selected	Automatically selected averaging time (sec.)			
0.1 sec	3	1	0.3	0.1
0.3 sec	10	3	1	0.3
1 sec	30	10	3	1
3 sec	100	30	10	3
10 sec	100	100	30	10
30 sec	100	100	100	30
100 sec	100	100	100	100
Switch-over frequency Hz (x1, log scale)	63 630 6.3K			

Switch-over frequencies x0.1, x1, x10 according to range.

Table 5.3. Selected EFFECTIVE AVERAGING TIME and BANDWIDTH with B & T PROGRAM selector in position "B & T Var. 3"

SELECTIVITY CONTROL position	Automatically selected bandwidth (Hz)		
1000 Hz	100	316	1000
316 Hz	31.6	100	316
100 Hz	10	31.6	100
31.6 Hz	3.16	10	31.6
10 Hz	3.16	3.16	10
3.16 Hz	3.16	3.16	3.16
EFFECTIVE AVERAGING TIME selected	Automatically selected averaging time (sec.)		
0.1 sec	1	0.3	0.1
0.3 sec	3	1	0.3
1 sec	10	3	1
3 sec	30	30	3
10 sec	100	100	10
30 sec	100	100	30
100 sec	100	100	100
Switch-over frequency Hz (x1, log scale)	200	2K	

Switch-over frequencies x0, x1 and x10 according to range.

Table 5.4. Selected EFFECTIVE AVERAGING TIME and BANDWIDTH with B & T PROGRAM selector in position "B & T Var. 4"

The actual bandwidth and effective averaging time in use at a particular instant are indicated by the appropriate light in the cluster surrounding the switches. The switch-over frequencies are indicated on the scale by black spots, and are separated by half decades for programmes 1 and 2. Six frequency ranges are defined as follows.

P_1 = 20– 63
P_2 = 63– 200
P_3 = 200– 630
P_4 = 630– 2000
P_5 = 2000– 6300
P_6 = 6300–20000

The ranges given are for the switch position "log x1."

For programmes 3 or 4, the switch-over frequencies are separated by a decade.

Programme 3 combines the ranges P_2 and P_3 and also P_4 and P_5. This gives a total of four ranges.

$P_1 = 20\text{–}63$
$P_2 + P_3 = 63\text{–}630$
$P_4 + P_5 = 630\text{–}6300$
$P_6 = 6300\text{–}20000$

Programme 4 combines the ranges P_1 and P_2, P_3 and P_4, and also P_5 and P_6. This gives a total of three ranges.

$P_1 + P_2 = 20\text{–}200$
$P_3 + P_4 = 200\text{–}2000$
$P_5 + P_6 = 2000\text{–}20000$

Remote Control of B & T Programmes

Remote control of the B & T Programmes is only possible if the V.C.O. is driven by an external voltage, and the frequency scale pointer is in the passive zone (i.e. blank portion of the scale).

A socket (EXT. B & T PROGRAM) on the rear panel of the 2010 enables the B & T Programme switch-over frequencies to be remote controlled. The pin connections to the socket are shown in Fig.5.9.

Having selected the desired programme using the three switches, B, T, and B & T PROGRAM, a switch-over is effected by shorting the appropriate pin to the centre terminal (ground), (see Fig.5.9). The switching from one set of conditions to another may be carried out at any frequency.

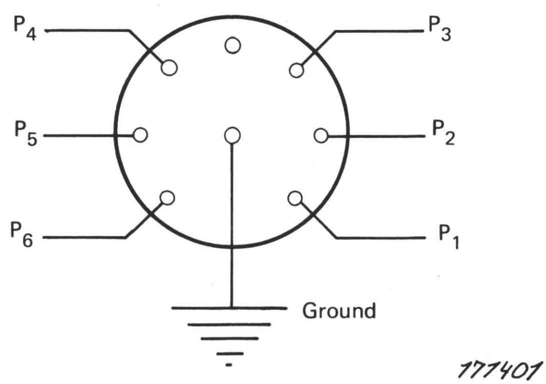

Fig.5.9. Pin connections of the EXT. B & T PROGRAM Socket (Viewed Externally)

5.4. BEAT FREQUENCY OSCILLATOR SECTION (B.F.O.)

A block diagram of the B.F.O. section is shown in Fig.5.10.

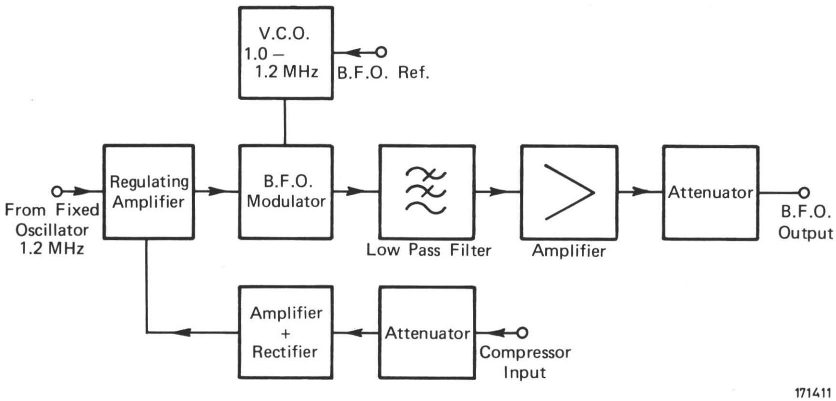

Fig.5.10. B.F.O. section block diagram

The generator section is comprised of a mixer which receives two frequencies:

a) f_o – a fixed frequency of 1.2 MHz from the fixed frequency section, and

b) f_v – a variable frequency (between 1.0 and 1.2 MHz) from the voltage controlled oscillator.

The B.F.O. output frequency is f_s where $f_s = f_o - f_v$. This frequency is displayed on the Nixie tube display and also indicated by the frequency scale pointer and scale range selector.

Before the mixing process, the 1.2 MHz fixed frequency signal is passed through a variable gain amplifier. The gain of the amplifier is controlled by a compression signal. The compression signal enters the 2010 at the socket marked COMPRESSOR INPUT. A variable potentiometer (COMPRESSOR VOLTAGE) controls the level of the compression signal, which is then passed through a full-wave rectifier. The integration time constant of the rectifying circuit is determined by the setting of the COMPRESSOR SPEED selector. Compression speeds of 3, 10, 30, 100, 300 and 1000 dB/sec are available. The signal from the rectifier is then used to control the variable gain (regulating) amplifier.

When the COMPRESSOR SPEED selector is in the "Comp. Off" position, the variable gain amplifier itself controls the output level.

If the B.F.O. stop push button is depressed, the variable gain amplifier receives a maximum compression signal which reduces the output of the amplifier to zero. This suppresses the output signal until the push button is released. The push button switch is noiseless and the output level falls by 80 dB in approximately 30 msec.

The output of the variable gain amplifier is then mixed with the signal from the V.C.O. After filtering and amplification, the resulting signal is fed to an attenuator (B.F.O. OUTPUT VOLTAGE) and a fixed gain output amplifier. Finally the signal may be fed to the B.F.O. ATTENUATOR, which selects the output range between 0.1 mV and 10 V. The output

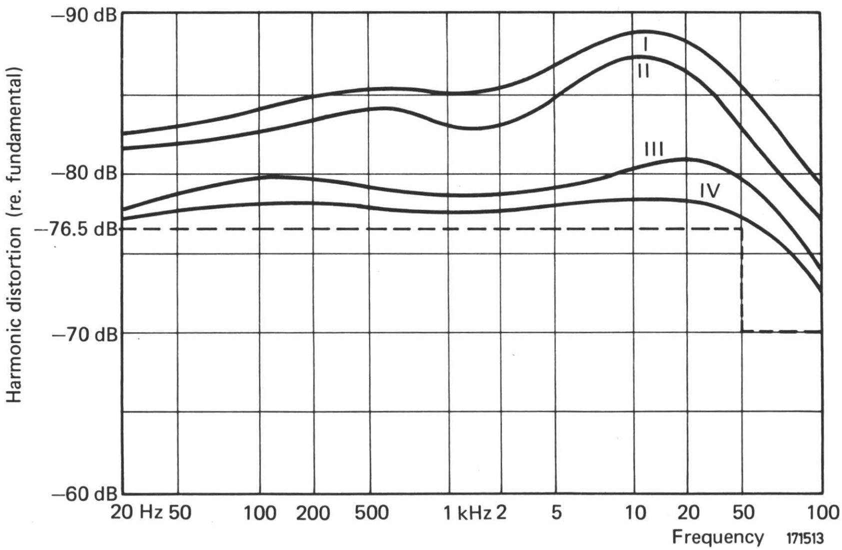

Fig.5.11. Typical distortion curves for different loads and output settings

I: 3.16 V_{RMS} (600 Ω Source Imp.), No Load
II: 10 V_{RMS} (600 Ω Source Imp.), No Load
III: 7 V_{RMS} (5Ω Source Imp.), 130 Ω Load
IV: 10 V_{RMS} (5 Ω Source Imp.), 130 Ω Load

impedance of the B.F.O. OUTPUT socket is then 600 Ω. If the B.F.O. ATTENUATOR is in the "10 V Source Imp. 5 Ω" position, the output is taken directly from the fixed gain output amplifier, and the output impedance is 5 Ω. The matching impedance is 140 Ω.

If the B.F.O. REF. SIGNAL push button is depressed, a fixed voltage is applied to the V.C.O. which, depending on the scale range factor chosen, produces a frequency at the B.F.O. OUTPUT socket of 100, 1000, or 10000 Hz. The signal voltage is a function of the B.F.O. ATTENUATOR and the B.F.O. OUTPUT VOLTAGE settings.

Fig.5.11 shown typical distortion curves depending on load and output settings.

Fig.5.12 shown typical distortion curves depending on compressor speed settings. The compression level is 26 dB in this case.

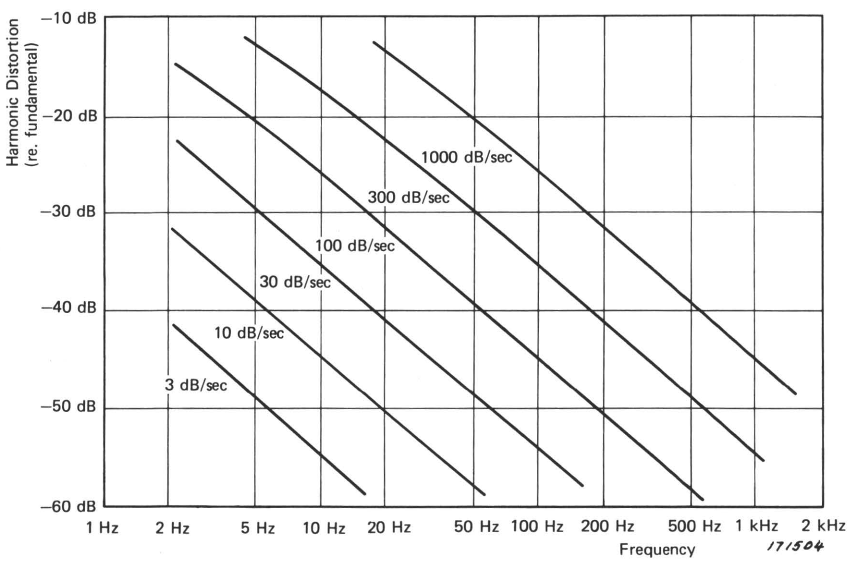

Fig.5.12. Typical distortion curves for different compressor speed settings

5.5. AUTOMATIC FREQUENCY CONTROL (A.F.C.)

The A.F.C. circuit enables the V.C.O. to be locked onto resonance peaks. The A.F.C. is actuated by depressing the appropriate push-button on the

Freq. Scale \ BW	3.16 Hz	10 Hz	31.6 Hz	100 Hz
x0.1	10	–	–	–
x1	10	100	100	–
x10	10	100	1000	1000

Table 5.5. Pull-in range of the A.F.C. Figures are given in Hz (Limit 0.5 dB error in level)

Freq. Scale \ BW	3.16 Hz	10 Hz	31.6 Hz	100 Hz
x0.1	1	–	–	–
x1	1	20	20	–
x10	1	20	200	400

Table 5.6. Pull-in speed of A.F.C. Figures are given in Hz/sec. (Limit 0.5 dB error in level)

front panel. The A.F.C. only operates in the four lower bandwidths (3.16 Hz to 100 Hz). The A.F.C. consists of a phase detector which compares the phase between a point in the third mixer and the output from the mixer, and produces a D.C. voltage depending on the phase difference. At a resonance point, where the phase difference is 90°, no DC voltage is produced. At a point away from the resonance, the DC voltage produced is fed into the V.C.O. until the resonance frequency is again reached.

The pull-in capability of the A.F.C. circuit depends on the scale range and the chosen bandwidth. The pull-in ranges are shown in Table 5.5. The pull-in or tracking speed of the A.F.C. circuit also depends on the scale range and bandwidth. The pull-in speeds are shown in Table 5.6.

6. USE WITH OTHER INSTRUMENTS

6.1. LEVEL RECORDERS TYPES 2305 AND 2307

6.1.1. General

In recording a frequency analysis from the 2010, the choice is available whether to record the unaveraged AC output or the RMS rectified signal from the DC output.

With the AC output from the 2010, RMS averaging of the recorded signal is performed entirely by the Level Recorder. The principal control of the Level Recorder which determines its averaging time is the WRITING SPEED selector. The averaging times given in Table 6.1 for the two Level Recorders are approximate values and are valid for measurement bandwidths greater than the minimum bandwidths specified.

WRITING SPEED mm/sec.	AVERAGING TIME sec.	MINIMUM MEASUREMENT BANDWIDTH Hz
1000	0.015	400
800	0.020	200
630	0.025	135
500	0.035	100
400	0.050	60
250	0.090	35
160	0.116	25
100	0.300	15
63	0.55	7
40	1.0	4
25	2.1	2
16	5.7	1
8	60.0	<1

Table 6.1. Relation between WRITING SPEED of the Level Recorders 2305 and 2307, and RMS signal averaging time

If the DC output from the 2010 is used, the Level Recorder should also be used in the DC mode. To minimize overshoot while making a DC recording and for the averaging time to override the averaging effect of the pen system, the Level Recorder's WRITING SPEED control should be set for an averaging time equal to, or less than, that selected on the 2010.

Once the effective averaging time, and the bandwidth are chosen a limit is then imposed on the maximum permissible scanning speed. The scanning speed must not be faster than that which will sweep a range equal to the bandwidth during a time equal to the averaging time.

This produces the relation

$$S \leqslant \frac{B}{T}$$

where S = scanning speed
B = selected bandwidth
T = averaging time – on 2010 for DC
on Recorder for AC

A relation can be derived from this equation, which will fix a value for the maximum permissible paper speed. An example of this calculation for a logarithmic sweep is given in Appendix 9.1. The result of this calculation requires that, using DRIVE SHAFT I of the Level Recorder

$$P \leqslant \frac{86.6\,\epsilon^2\,B^2}{f} \text{ mm/sec} \qquad (1)$$

where B is the measurement bandwidth (Hz)
f is the highest measurement frequency (Hz), and
ϵ is the maximum permissible error
P is the paper speed (mm/sec)

A similar calculation for a linear sweep (assuming the same scan drive as for the log sweep) produces the requirement that:

$$P \leqslant \frac{600\,\epsilon^2\,B^2}{f_u} \qquad (2)$$

where B is the measurement bandwidth (Hz)
f_u is the upper limit of the frequency range (i.e. 2, 20, or 200 kHz), and
ϵ is the maximum permissible error
P is the paper speed (mm/sec)

Note: In equation (1) f is the highest measuring frequency, which may be different from the limit of the range considered. On the other hand for a linear sweep, even if the range of frequencies investigated is inside the selected range the scanning speed limit is always the same.

The choice between a linear and a logarithmic sweep is discussed in the following section.

6.1.2. Linear and Logarithmic Scanning

The 2010 enables either a linear or a logarithmic frequency sweep to be made on all three frequency ranges 2 Hz – 2 kHz, 20 Hz – 20 kHz and 200 Hz – 200 kHz. The choice between the two sweeping modes may be made to suit the particular application. Although logarithmic sweep is the most widely used, certain applications are well suited to a linear scan.

For example:

1. Detailed investigation of closely spaced pure tones (e.g. harmonics) at high frequencies.
2. Accurate graphical measurement of Q factor of a resonance from the half power points.
3. Analysis in a narrow frequency band, which allows accurate frequency determination from recording paper.

6.1.3. Recording Procedure

DC Recording

Recording from the DC output of the 2010 utilizes the wide dynamic range (60 dB) and the wide range of selectable averaging times of the RMS rectifier.

The controls of the Level Recorders are shown in Figs.6.1 and 6.2. The procedure for recording an analysis is as follows:

1. Connect the instruments as shown in either Fig.6.3 or Fig.6.4. The scanning facility of the 2010 may be mechanically driven using the

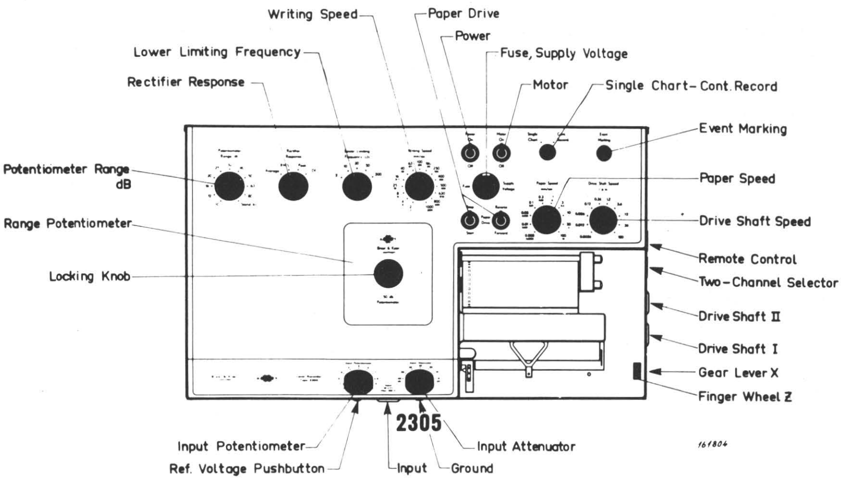

Fig.6.1. Level Recorder 2305 Controls

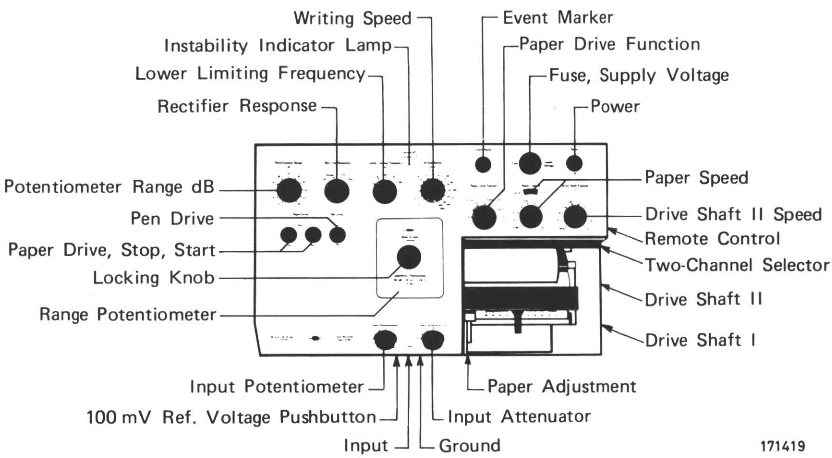

Fig.6.2. Level Recorder 2307 Controls

drive shaft UB 0041, connected to the paper drive shaft (DRIVE SHAFT I) on the Level Recorder. The SWEEP CONTROL selector on the 2010 should be in position "Ext. Mech.". Alternatively, the 2010 may be electrically driven from the Level Recorder 2307. In this case, an 8 core cable AQ 0034 must be connected between the X INPUT socket on the Level Recorder and the FREQUENCY CONTROL VOLTAGE "In" socket on the rear panel of the 2010. The SWEEP CONTROL selector on the 2010 should be in position "Ext. Volt".

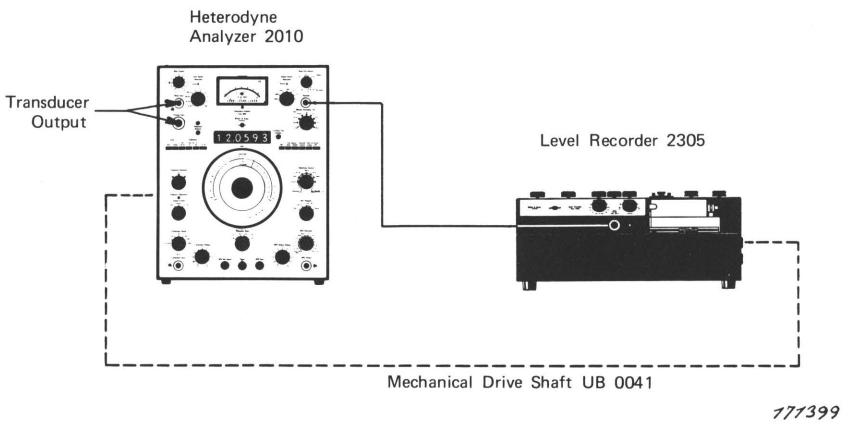

Fig.6.3. Interconnection of the 2010 and the 2305

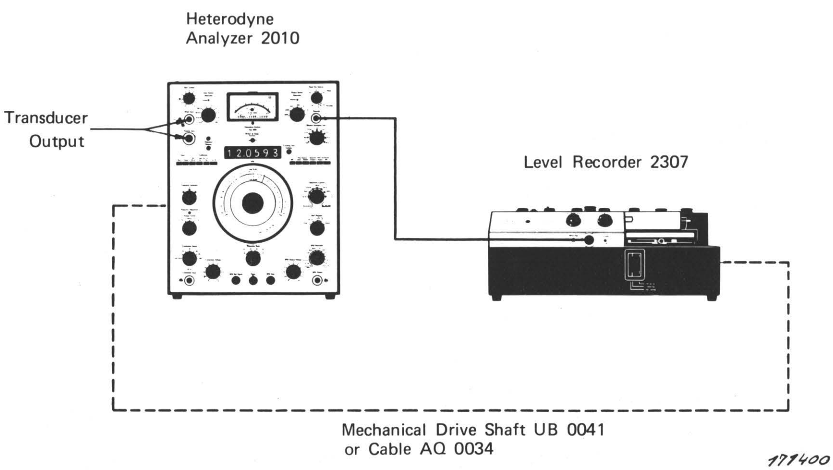

Fig.6.4. Interconnection of the 2010 and the 2307

2. The controls on the 2010 should be selected according to the type of analysis being made. Reference should be made to sections 4.1 to 4.4 on measurements, and also to Appendix section 9 for information on use of B & T programmes.

3. Set the control knobs on the Level Recorder to:

POTENTIOMETER RANGE	According to potentiometer used
RECTIFIER RESPONSE	"DC"
WRITING SPEED	As required. See table 6.1
LOWER LIMITING FREQUENCY	Any value on 2307, or any value below "200 Hz" for 2305, consistent with stable operation of the Recorder
POWER	"On"
MOTOR (2305) PEN DRIVE (2307)	"On"

4. The INPUT POTENTIOMETER and the INPUT ATTENUATOR of the Level Recorder can be adjusted so that the pen deflection corresponds to the meter deflection on the 2010. To do this set the READ OUT SELECTOR to "DC" and calibrate the instrument as described under the appropriate section for voltage, sound or vibration in section 3.2.

SOUND

a) Using a Pistonphone (124 dB) or Sound Level Calibrator (94 dB) the pen should be adjusted to 4 dB above one of the thick lines on the Recording Paper. The thick line then corresponds to 120 or 90 dB respectively.

b) Using the 50 mV RMS Reference Signal provided in the 2010 adjust the meter deflection to correspond to the Microphone open circuit sensitivity given on the microphone calibration chart. Note the equivalent value on the dB scale, and set the pen deflection to this value on the recording paper.

VIBRATION

a) When Accelerometer Calibrator 4291 or 4292 is used, 0.707 g RMS corresponds to 3 dB below full scale. The pen should be set to 3 dB below one of the thick lines on the recording paper. The thick line will then correspond to an acceleration level of 1 g RMS.

b) Using the 50 mV RMS signal provided in the 2010, note the difference in dB between the calibration signal (see section 3.2.3) and the full scale deflection. The pen should be set to this number of dBs below a thick line. This line then represents the maximum deflection of the scale used (10 g in the example in section 3.2.3).

VOLTAGE
The 50 mV RMS signal provided in the 2010 corresponds to 6 dB below full scale deflection for a meter range of 100 mV. The pen should be set to 6 dB below the upper thick line on the recording paper. This line will then correspond to 100 mV.

Note: The values given to the reference lines only apply provided the positions of the attenuators of the 2010 and Level Recorder are not changed. However if the attenuator settings are changed, the value of the reference line is changed by the corresponding number of dB.

5. Two types of recording can be made.

a) *CONTINUOUS RECORDING*

1. *With the Type 2305.* For recording over any chart length the GEAR LEVER on the 2305 can be in either position. When the lever is "In", the required paper speed may be set using the large figures around the PAPER SPEED selector. When the lever is "Out" the small figures apply.

   To start the paper moving, first set the PAPER DRIVE switches to "Stop", and "Forward". Then depress the SINGLE CHART/ CONT. RECORD push-button and turn clockwise to lock in. To stop, release the push-button.

2. *With the Type 2307.* For recording over any chart length with the 2307, the PAPER SPEED switch can be in either position (cm/sec., or mm/sec.) and the figures around the PAPER SPEED selector apply to both positions.

   To start the paper moving, first set the PAPER DRIVE FUNCTION selector to "Continuous, F", and then press the PAPER DRIVE, "Start" push-button. To stop, press the PAPER DRIVE, "Stop" push-button.

b) *SINGLE CHART RECORDING*

1. *With the Type 2305.* For automatic recording over one 250 mm chart length, the GEAR LEVER should be in the "Out" position, and the paper speed may be selected according to the small figures around the PAPER SPEED selector.

   To start the paper moving, first set the PAPER DRIVE switches to "Start" and "Forward". Then depress the SINGLE CHART/ CONT. RECORD push-button and release after the chart has travelled at least 40 mm. The paper will continue to move, but will stop automatically after one chart length or less. The second recorded chart (after realigning the paper to the start of its sweep) will be 250 mm in length.

2. *With the Type 2307.* For automatic recording over one 250 mm chart length, the PAPER SPEED switch should be in the "mm/sec" position, and the paper speed may be selected according to the figures around the PAPER SPEED selector.

   To start the paper moving, first set the PAPER DRIVE FUNCTION selector to "Automatic stop F" and then press the "PAPER DRIVE, Start" button. The paper travels for one chart length and is then stopped automatically.

6. Once the paper has stopped adjust the Finger Wheel so that the stylus coincides with the reference line to be used. To remove backlash in the paper drive, the paper should be moved so that it approaches the correct position in the reverse direction (i.e. towards the recorder). For example, if the paper is to be shifted to a higher frequency, the chart is first moved forward to a position beyond the desired point and then reversed to the correct position.

7. Position the SWEEP CONTROL selector of the 2010 on "Manual" and select the range for analysis on the FREQUENCY SCALE selector. If the mechanical drive is used, position the frequency scale pointer on the appropriate starting frequency, as indicated on the Level Recorder paper. Position the SWEEP CONTROL selector on "Ext. Mech.".

   If the electrical drive from the 2307 is used, it is necessary to position the scale pointer of the 2010 in the passive zone. In this case the position of the paper in the Level Recorder determines the analysis frequency. Position the SWEEP CONTROL selector on "Ext. Volt."

8. If required, the frequency marking facility of the 2010 may be used with the Level Recorder. The control cable AQ 0027 for the Type 2305, (AQ 0035 for the Type 2307) is connected between the OVERLOAD AND FREQUENCY MARKING socket on the rear panel of the 2010 and the REMOTE CONTROL socket on the Level Recorder. The appropriate digit for marking may be selected on the rear panel of the 2010.

   Note: The cable for electrical drive of the 2010 is connected between the X INPUT socket on the side panel of the 2307, and the FREQUENCY CONTROL VOLTAGE "In" socket on the rear panel of the 2010.

   However the PAPER DRIVE FUNCTION selector on the 2307 should *not* be placed in the "X-Rec." position.

9. Start the recording as indicated in point 5.

AC Recording

The dynamic range of the AC output is given in Table 6.2.

This indicates that it will normally be possible to employ any of the Logarithmic Range Potentiometers with the Level Recorder.

INPUT SECTION ATTENUATOR

OUTPUT SECTION ATTENUATOR	10 mV	30 mV	100 mV–300 V
x0.001	>10 dB	>20 dB	>30 dB
x0.003	>20 dB	>30 dB	>40 dB
x0.01	>30 dB	>40 dB	>50 dB
x0.03	>40 dB	>50 dB	>60 dB
x0.1	>50 dB	>60 dB	>70 dB
x0.3	>60 dB	>70 dB	>78 dB
x1	>70 dB	>80 dB	>84 dB

Table 6.2. Dynamic range and AC output of the 2010 as a function of attenuator settings*

* Dynamic range is defined here as the range from the RMS overload level with a sine signal down to the RMS noise level.

Procedure will be the same for each Logarithmic Range Potentiometer, providing the POTENTIOMETER RANGE switch is in the correct position.

For recording an analysis, procedure is similar to that indicated under DC Recording, *except* for the following amendments. The item numbers are those used in the DC Recording section.

2. EFFECTIVE AVERAGING TIME of the 2010 can be set to "Fast" in order to obtain meter monitoring of the output signal.

3. RECTIFIER RESPONSE of the Level Recorder should be set to "RMS" and the LOWER LIMITING FREQUENCY to a value below the lowest frequency required from the analysis.

4. The READ OUT SELECTOR on the 2010 should be set to one of the "AC" positions.

6.1.4. Control of the Level Recorder 2307 by the 2010

The paper drive of the 2307 Level Recorder may be controlled by the frequency control voltage output from the 2010. The cable AQ 0034 is connected between the X INPUT socket on the 2307 and the FREQUENCY CONTROL VOLTAGE "Out" socket on the rear panel of the 2010. The PAPER DRIVE FUNCTION selector on the 2307 must be set to "X-Rec.".

6.2. TAPE RECORDING

For many applications regarding the measurement of sound and vibration, the B & K Tape Recorder 7001 may be very useful when employed with the 2010.

The 7001 has four tape speeds ranging from 1.5 to 60 inches/sec and provides two measurement channels and a monitor channel. The measurement channels have a linear response ranging from DC up to 20 kHz depending on the tape speed selected. It can be connected directly to the RECORDER socket of the 2010 as shown in the recording set-up in Fig.6.5. The measuring amplifier section of the 2010 is well suited to this application, and can serve as a high quality linear input amplifier to the recorder. The AC output should be selected.

The 2010 can also be used as an input amplifier to other types of tape

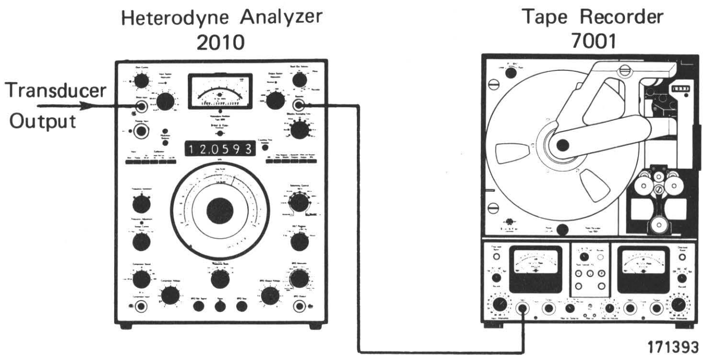

Fig.6.5. Recording with 7001 Tape Recorder

recorders provided that their input impedance is greater than 5 kΩ. For recorders with a recording level considerably less than 10 V RMS, the circuit in Fig.6.6 should be used to attenuate the recorder's input signal, as this gives a better signal-to-noise ratio than using the output attenuator of the 2010.

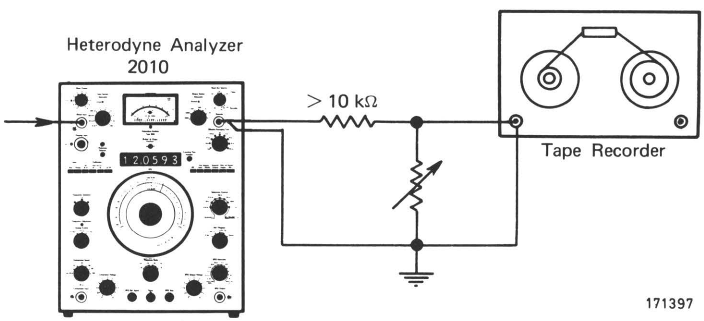

Fig.6.6. Attenuation of 2010 output for tape recording

For an analysis of a tape recording, the information to be processed is made into a tape loop and fitted to the loop adapter of the 7001 in the instrument set-up shown in Fig.6.7. Synchronization between the tuning frequency of the 2010 and the paper movement of the Level Recorder is obtained using the Flexible Drive Shaft UB 0041 connected between the two instruments.

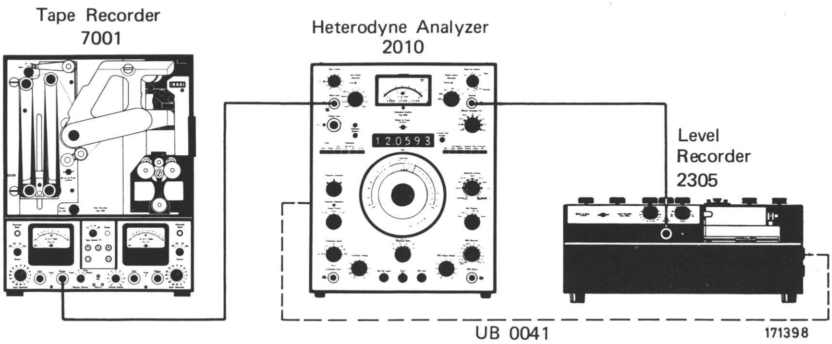

Fig.6.7. Frequency analysis using 7001 Tape Recorder

Tape splice noise in the recorded loop can be excluded from the analysis using the B & K Type 2972 Tape Signal Gate. For details see the instruction manual for the Type 2972.

6.3. USE WITH THE HETERODYNE SLAVE FILTER 2020

6.3.1. General

Addition of the Heterodyne Slave Filter Type 2020 connected as an external filter to the 2010 enables synchronous filtering of signals. In the example shown in Fig.6.8, filtering of the compressor signal enables control of the exciter level at the fundamental frequency only and allows response measurements at very low levels or in the presence of high ambient noise signals.

The filter tuning signals for the 2020 are provided by sockets marked TO 2020 on the rear panel of the 2010. The connections are made between the

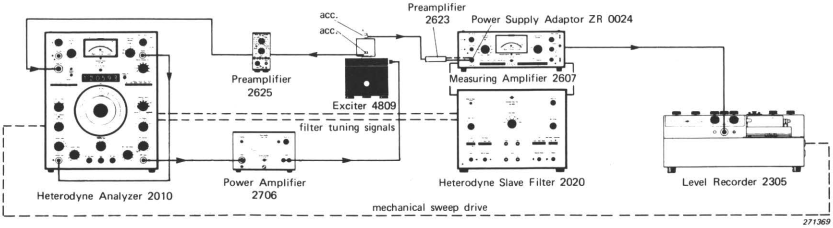

Fig.6.8. Use of the 2010 and the 2020 in a regulated system

sockets "Fixed. Freq. 120 kHz" on the 2010 rear panel and "120 kHz" on the 2020 rear panel, and between "Var. Freq." on the 2010 and "120 – 100 kHz" on the 2020. The push-button B.F.O. MODE "Sine" must be selected on the 2020. For further details on the operation of the slave filter, reference should be made to the 2020 instruction manual.

The internal wiring of the 2010 is such that only the "x 1" frequency range* can be used with the 2020. This range corresponds to the nominal frequency range of the 2020 (i.e. 20 Hz – 20 kHz). However as the actual frequency range of the 2020 can extend below the nominal lower limit, investigations can be carried out at lower frequencies using the "Lin x 1" range on the 2010.

Four filter bandwidths are available on the 2020, i.e. 3.16, 10, 31.6, and 100 Hz. The filter bandwidth may be selected manually or by remote control.

6.3.2. Remote control of the 2020 when used with the 2010

When the bandwidth selector on the 2020 is in the position "Auto", the filter bandwidth can be selected by grounding the appropriate pin on the REMOTE BANDWIDTH CONTROL socket on the rear panel of the 2020. The pin connections of this socket are shown in Fig.6.9. If no connection is made to this socket the filter bandwidth is automatically 3.16 Hz.

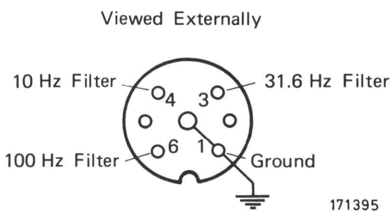

Fig.6.9. Pin connections of the Remote Bandwidth Control Socket on the 2020

When the scanning facility of the 2010 is mechanically driven, a pin on the EXT. B & T PROGRAM socket on the rear panel will be grounded

* The variable frequency output (Var. Freq.) from the 2010 only corresponds to the "x 1" frequency range, independent of the actual frequency range selected on the 2010.

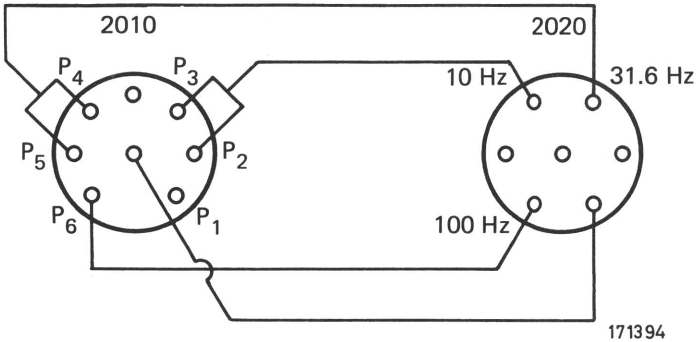

Fig.6.10. Example of connection for remote control of the 2020 by the 2010

during the time the scale pointer is in the particular range corresponding to that pin. For details, see Section 5.3.5.

Interconnection of the pins on the REMOTE BANDWIDTH CONTROL socket on the 2020 and the pins on the EXT. B & T PROGRAM socket on the 2010 will enable remote control of the filter bandwidth switching on

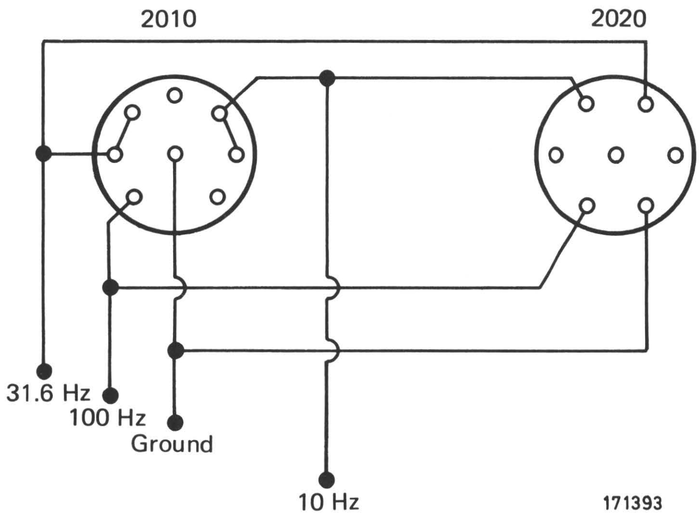

Fig.6.11. Example of connection for remote control of the 2020 and the 2010

the 2020 dependent on the indicated frequency on the 2010. It is possible to connect two different pins on the 2010 to the same pin on the 2020. This may be useful to synchronize the selectivity of the 2020 and the 2010, when a B & T programme is used on the analyzer. For example, if the sockets are interconnected as shown in Fig.6.10 and the B & T PROGRAM selector on the 2010 is in position "3", and the SELECTIVITY CONTROL is on "100 Hz", then the filter bandwidths on the 2010 and 2020 have the same value and are switched synchronously throughout the frequency range.

However, if both the 2010 and the 2020 are to be remote controlled by some external apparatus, the scanning facility on the 2010 must be electrically driven (see section 4.6.2). Parallel connections must be made between the pins of the REMOTE BANDWIDTH CONTROL socket on the 2020, and the EXT. B & T PROGRAM socket on the 2010. Interconnection to perform the same operation given in the preceding example is shown in Fig.6.11. The switching is remote controlled by grounding the termination corresponding to the filter bandwidth required.

7. APPLICATIONS

The versatility of the 2010 enables the instrument to be used for many applications in acoustics and vibration. A few possible applications are outlined below.

7.1. CONSTANT AND PROGRAMMED BANDWIDTH ANALYSIS

Analysis with a constant or programmable bandwidth down to 3.16 Hz enables accurate frequency determination which may be important for instance in machine noise or vibration investigations.

The recording shown in Fig.7.1a is an analysis of the vibration obtained on the housing of a small electric motor. The transducer used is a B & K Type 4339 Accelerometer. The set-up is shown in Fig.7.2.

In order to make a further investigation of the peaks in the range 250 Hz to 400 Hz, the frequency scale can be changed to "Lin x 0.1", and the

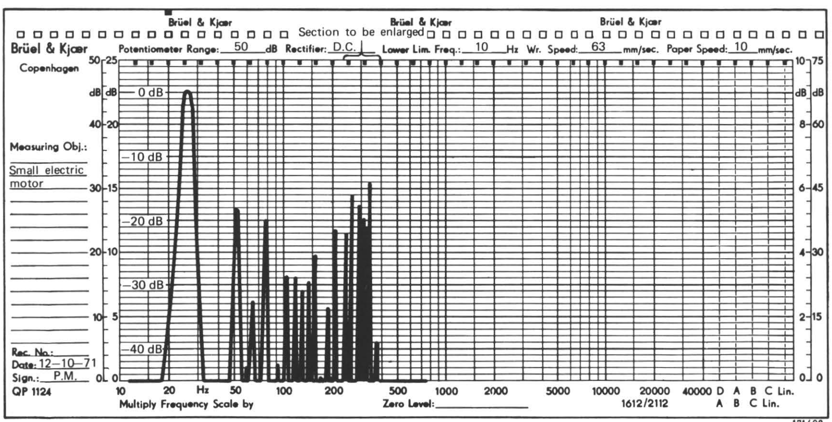

Fig.7.1.a. Frequency analysis of the vibrations of a small electric motor (Log. sweep)

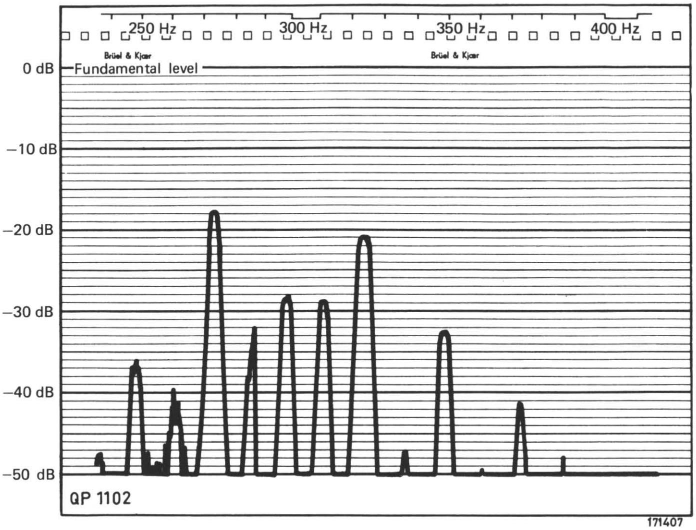

Fig.7.1.b. Frequency analysis of the vibrations of a small electric motor (Lin. sweep)

frequency marker function of the 2010 connected to control the event marker of the recorder. The resulting recording, shown in Fig.7.1b, gives the enlarged section with the frequency calibration at the top of the paper which enables very accurate frequency determination of the peaks.

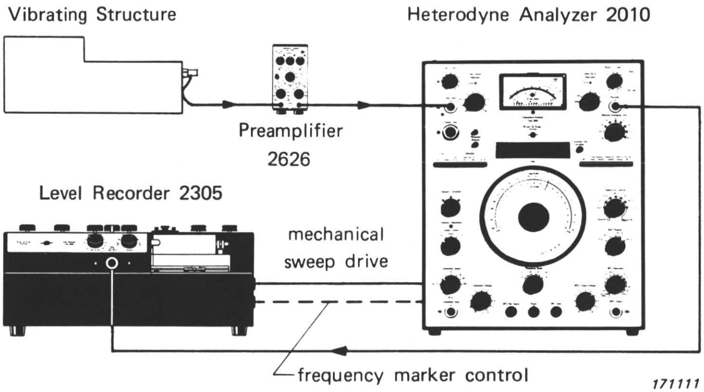

Fig.7.2. Set-up for recording Vibration spectra

7.2. FREQUENCY RESPONSE MEASUREMENTS

The ability to regulate the output from the B.F.O. section with a feed-back signal (compressor circuit) enables the 2010 to be used as a complete frequency response measurement system. The B.F.O. section can be used to excite the specimen at a constant chosen level, and the analyzer section will then measure the response directly.

Two applications are shown below, one on vibration, and the other on acoustics.

7.2.1. Frequency response of a microphone probe

Probe microphones can be used for a variety of applications such as measurements in the ear, measurement of sound insulating material and at points within intricate machinery which would normally be inaccessible.

The B & K Probe Microphone Kit UA 0040 contains probes of different diameters and all the necessary accessories for calibration and damping of the probes.

Fig.7.3 shows the frequency response of an undamped 2 mm diameter microphone probe (24 cm long). Further response measurements will show the effectiveness of damping the probe.

Fig.7.4 shows the measurement set-up.

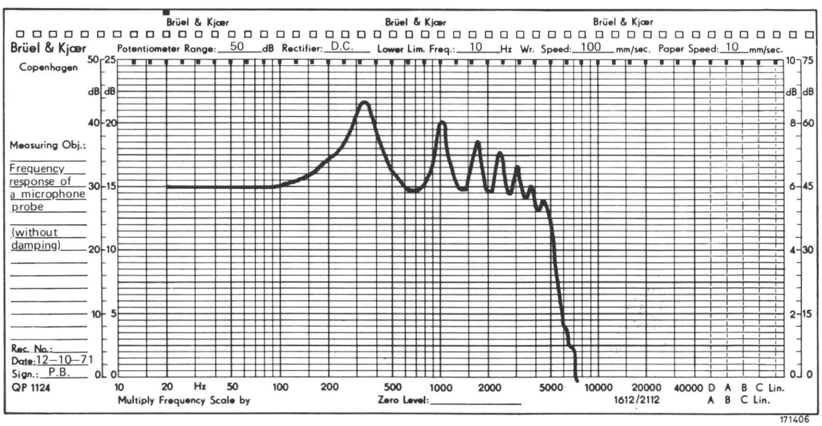

Fig.7.3. Frequency response of an undamped microphone probe

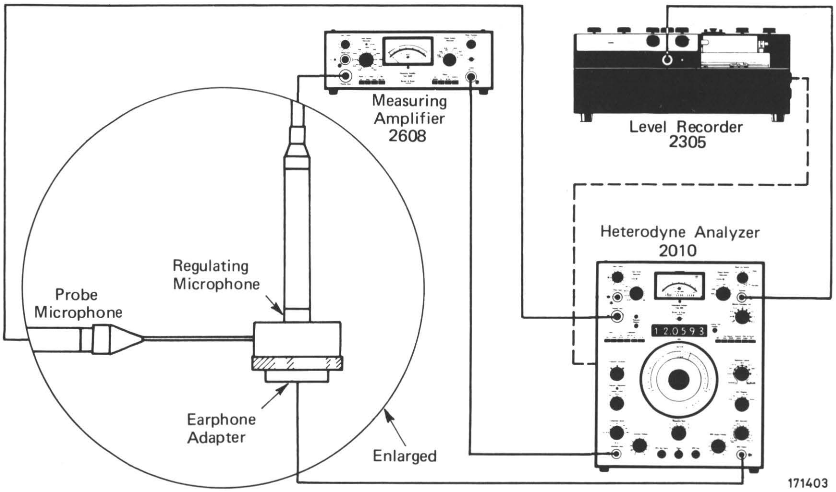

Fig.7.4. Set-up for recording the frequency response of a microphone probe

7.2.2. Frequency response of a B & K Minishaker Type 4810 at low levels

Fig.7.5 shows a frequency response of a minishaker being driven by the B.F.O. output of the 2010 at a low vibration level. Due to the amplitude linearity of the B.F.O. output (± 0.2 dB over the whole range) it is not necessary to compress the output signal with this particular set-up. However

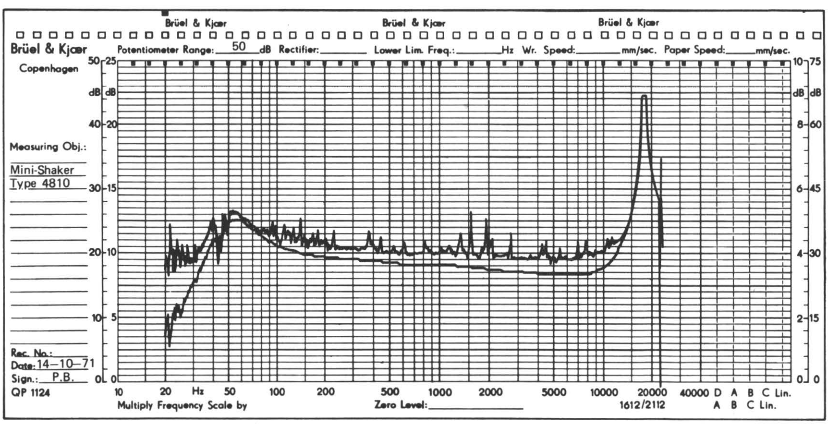

Fig.7.5. Frequency response of a mini-shaker 4810 at low levels

the signal should be compressed if the load impedance varies considerably with frequency.

The upper curve was recorded with the analyzer in the linear mode. It shows the signal level is of the same magnitude as the background noise and cannot be recorded without using narrow band analysis. The lower curve shows the same signal recorded with the analyzer in the selective mode (3.16 Hz bandwidth). Only the fundamental originating from the B.F.O. is recorded, thus the influence of noise, spurious vibration, and harmonic distortion is rejected.

7.3. SOUND ABSORPTION MEASUREMENTS

Measurement of the acoustic absorption coefficient of a material may be made by inserting a small sample of the material into an acoustic transmission line and measuring the maxima and minima of the standing waves obtained.

Fig.7.6 shows a typical measuring set-up using the 2010 with the B & K Standing Wave Apparatus Type 4002. The Absorption Coefficient can be read directly from the 2010 if scale SA 0054, available on request, is used. Selective reception is necessary if measurements are made on materials with very low absorption coefficient as the minima are at a very low level. The specific acoustic impedance of a material may also be determined by this method. Reference should be made to the instruction manual for the Type 4002 for further details.

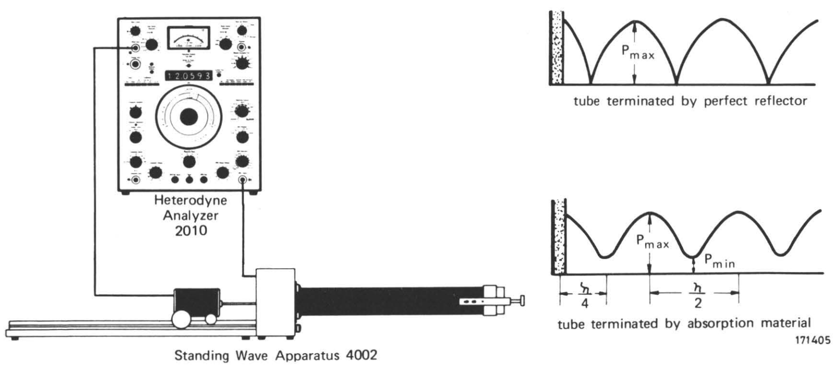

Fig.7.6. Sound Absorption measurements

8. ACCESSORIES

8.1. GENERAL

The combinations of accessories that can be used with the 2010 for the measurement and analysis of sound and vibration can be seen in Figs.8.1 and 8.2. The specifications of these accessories can be found in the B & K Catalogues which are available through any B & K Agent.

8.2. RACK MOUNTING

The 2010 is available in "A", "B" and "C" models. Model "A", the standard version, is the 2010 in a light metal cabinet. The addition of a mahogany case KA 0010 makes the "B" model, or alternatively the addition of a 19 inch metal rack mounting kit KS 0001 makes the "C" model. Both the mahogany frame and the metal rack mounting kit are available separately.

For mounting a combination of B & K instruments together in one unit the following frames are available:

Rack KQ 0037: accepts the 2010 together with the Level Recorder 2305 or 2307.

Rack KQ 0038: accepts the 2010 together with the Level Recorder 2305 or 2307, and one of the filters Type 2020, Type 1614 or Type 1615.

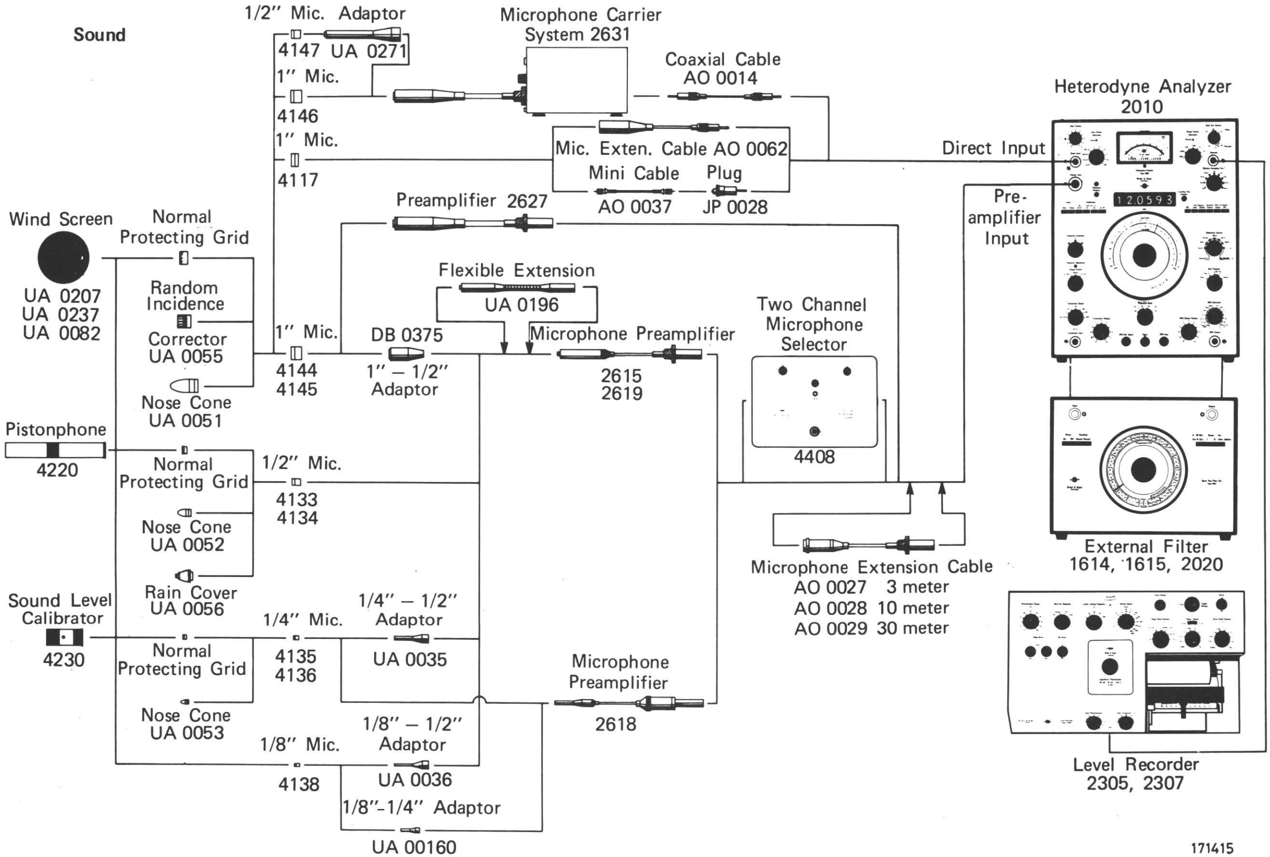

Fig.8.1. Accessories for Sound Measurement

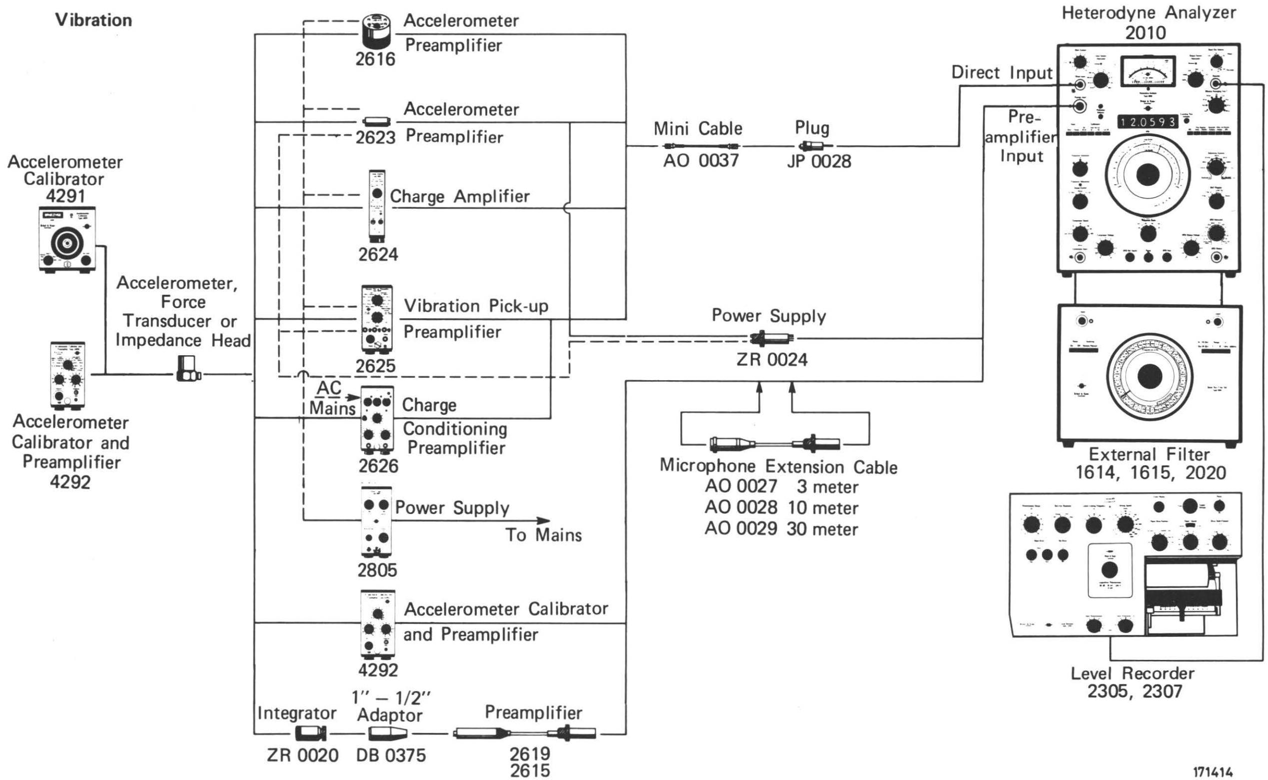

Fig.8.2. Accessories for Vibration Measurements

9. APPENDIX 1

9.1. OPTIMIZATION OF SPECTRAL ANALYSIS RECORDING

Using logarithmic sweep

The primary factors which affect the optimization of spectral analysis recording are as follows:

Maximum permitted statistical error
Scanning speed
Measuring time
Relative resolution required

The statistical error, ϵ, of an RMS measurement* is given by:

$$\epsilon = \frac{1}{2\sqrt{BT}} \qquad (1)$$

where B = measurement or signal frequency bandwidth (Hz)
T = averaging time (sec)

Also, the analyzer should sweep, at most, one bandwidth during one averaging time. This determines a scanning speed (S). If the effective averaging time T is fixed on the 2010, then

$$S \leqslant \frac{B}{T} \qquad (2)$$

S is the scanning speed in Hz/sec.

If equations (1) and (2) are combined at the limit where T = B/S, then

$$S = 4\,\epsilon^2\, B^2 \qquad (3)$$

---

* The statistical error of spectral density measurements is $\epsilon = \frac{1}{\sqrt{BT}}$. For derivation of these formalae, see the B & K booklet "Frequency Analysis and Power Spectral Density measurements".

When using the Level Recorder Type 2305, or 2307 with the calibrated recording paper QP 1124, the relationship between paper travel and frequency indication, f Hz is:

$$x = 50 \log_{10} (f/10)$$

where x is the distance in mm travelled from the 10 Hz line.

Therefore:

$$\frac{dx}{df} = \frac{50}{f} \log_{10} e = \frac{21.7}{f} \text{mm/Hz} \tag{4}$$

The scanning speed

$$S = P/(dx/df) \text{ Hz/sec}$$

where P is the paper speed in mm/sec.

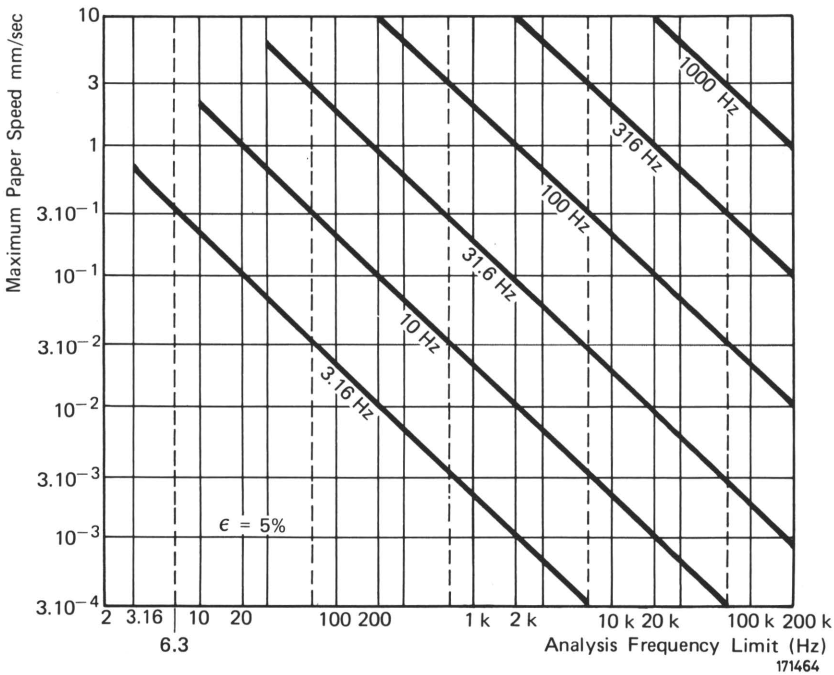

Fig.9.1. Selection of maximum paper speed for less than 5% statistical error

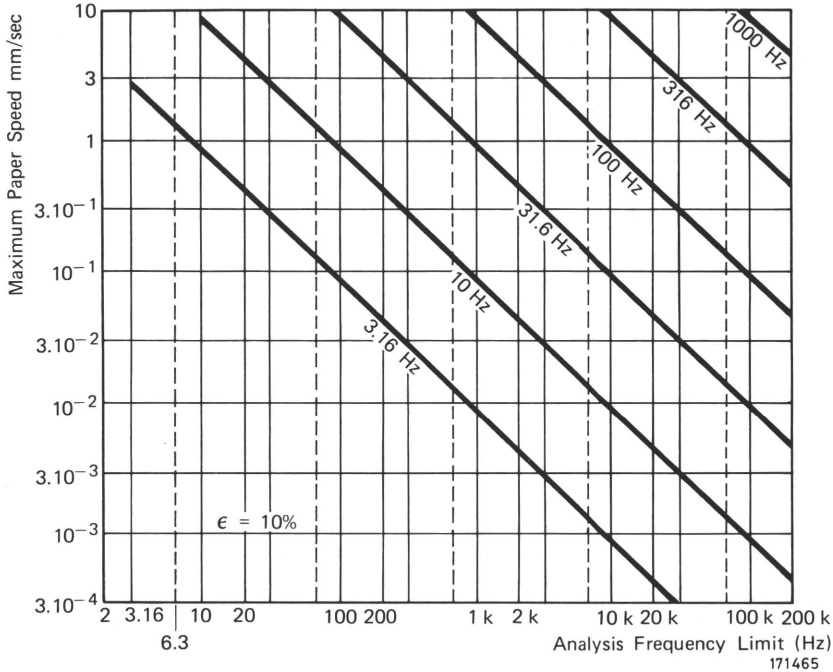

Fig.9.2. Selection of maximum paper speed for less than 10% statistical error

Therefore:

$$S = \frac{P \cdot f}{21.7} \tag{5}$$

Hence, for a maximum permissible error ϵ, the requirement reduces to:

$$P \leqslant \frac{86.6\, \epsilon^2\, B^2}{f} \tag{6}$$

where B is the measurement bandwidth
f is the highest measurement frequency

It can be seen that the factor $\frac{B^2}{f}$ plays an important role. In effect, if a constant bandwidth is used, the bandwidth should be small in order to obtain an acceptable resolution at low frequencies. Also, as the frequency f in the denominator is the highest frequency considered by the analyzer, the measuring time over a wide frequency range may be very long.

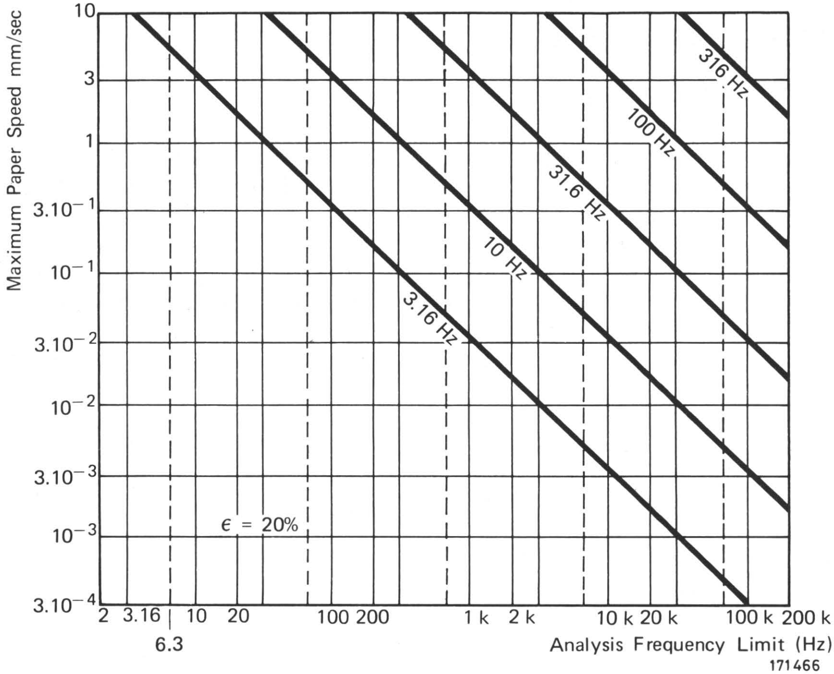

Fig.9.3. Selection of maximum paper speed for less than 20% statistical error

This measuring time may be reduced by use of the B & T programmes available in the 2010.

Fig.9.1 to 9.3 are nomographs which enable the maximum permissible Paper Speed to be obtained corresponding to the Analysis Frequency Limit, and a Statistical Error ϵ. The nomographs are for a mechanical scan drive from the DRIVE SHAFT I socket on the Level Recorder, or for an electrical drive from the X INPUT of the Type 2307 Level Recorder. A 1/1 gear ratio on the 2010 is also assumed.

However, DRIVE SHAFT II on the Level Recorder and/or the 10/1 gear ratio on the 2010 may be used, but the values given for Maximum Paper Speed in the nomograph must be modified accordingly.

9.2. B & T PROGRAMMES

9.2.1. B and T variable

The two programmes (positions "3" and"4" on the B & T PROGRAM selector) allow the product of bandwidth (B) and averaging time (T) to be kept constant while progressively increasing the bandwidth with frequency. This enables the ratio B^2/f to be the same at the different transition frequencies. For a given bandwidth the maximum frequency to be considered in equation 6 is the first transition, or switchover, frequency. This enables the value of the frequency f in equation (6) to be reduced. Therefore the measuring time can be reduced considerably without any sacrifice of the relative resolution.

Reference should be made to Tables 5.3 and 5.4 for choice of programme for a particular application. Reference should also be made to section 4.6 on remote control of these programmes.

9.2.2. T variable

This programme (position 2 on the B & T program selector) enables the product T x f to be kept practically constant at the switchover frequencies. The bandwidth B is kept constant at any selected value throughout the measurement. See Table 5.2.

This programme is of particular use in the study of deterministic signals with discrete frequency components only (the study of harmonic distortion for example). The same relative error on all the components is obtained, as shown in the following calculation:

For a logarithmic sweep, the minimum time, t, taken to sweep through a frequency f_o, with a filter bandwidth B, is:

$$t = \int_{f_o - \frac{B}{2}}^{f_o + \frac{B}{2}} K \, df/f$$

where K is a constant with dimensions of time.

$$t = K \log_e \frac{f_o + \frac{B}{2}}{f_o - \frac{B}{2}}$$

$$t = K \log_e \frac{1 + \frac{B}{2 f_o}}{1 - \frac{B}{2 f_o}}$$

$$t = K \left[\log_e \left(1 + \frac{B}{2 f_o}\right) - \log_e \left(1 - \frac{B}{2 f_o}\right)\right]$$

if B is small compared with f_o

then

$$t \doteq K \frac{B}{f_o}$$

As t x f is constant, i.e. $T = K'/f$

then at the frequency f_o

$$\frac{t}{T} = \frac{KB}{K'}$$

If the requirement $S \leqslant B/T$ is satisfied, that is, that $t \geqslant T$, then no error due to rate of scan is obtained on the RMS value of the component. Also a scanning speed which is faster than that which would be available on a T constant programme, may be used.

However, if a faster scanning speed than will satisfy the requirement $S \leqslant B/T$, is selected, the relative error on a component is only dependent on $\sqrt{\frac{t}{T}}$ Therefore the relative error is constant, and the *difference* in level measured in dB between the different components will be the same, as if the requirement had been satisfied. For example, in distortion measurements where relative values are required, this will give the true value of distortion, but *not* the true individual value of each component.

9.2.3. B variable

This programme (position 1 on the B & T PROGRAM selector) allows the ratio B/f to be kept constant at the switchover frequencies. See Table 5.1. The preceding calculation shows that the time spent on one given component ($t \triangleq K\ B/f$) can now be kept constant, because the ratio B/f can be kept constant.

Also, the time, t, taken for a filter of bandwidth B to pass through a frequency band Δf is given by

$$t_1 = \int_{f_o - \frac{\Delta f}{2} - \frac{B}{2}}^{f_o + \frac{\Delta f}{2} + \frac{B}{2}} K\ df/f$$

$$t_1 = K \log_e \frac{f_o + \frac{\Delta f}{2} + \frac{B}{2}}{f_o - \frac{\Delta f}{2} - \frac{B}{2}}$$

$$= K \log_e \left[\frac{1 + \frac{\Delta f}{2 f_o} + \frac{B}{2 f_o}}{1 - \frac{\Delta f}{2 f_o} - \frac{B}{2 f_o}} \right]$$

If the case of two resonances with the same Q factor is considered, where $Q = f_o/\Delta f$, it can be seen from the equation that the time spent on sweeping each resonance will be the same. Also, as the Effective Averaging Time is kept constant, the recordings of the resonances will be identical. The relative resolution will also be the same.

9.3. LOWER FREQUENCY LIMIT

In a selective analysis, the analysis bandwidth used imposes a lower limit to the frequencies measurable without introducing inconsistent measuring errors. In practice, it is not recommended to analyse frequencies lower than the bandwidth.

The first mixer receives two signals, the input signal at a frequency f_s, and the signal from the V.C.O., $f_o - f_s$. Assuming the mixer is balanced, two frequencies are obtained at the output: f_o and $f_o - 2\ f_s$. When f_s is sufficiently large, the signal $f_o - 2\ f_s$, is filtered and does not appear in the reading. Conversely, if f_s approaches zero, $f_o - 2\ f_s$ is not filtered and a 3 dB error can be introduced into the reading.

If $f_s = B/4$ (i.e. $2 f_s = B/2$), the component $f_o - 2 f_s$ is attenuated by 3 dB, which introduces a meter error of 1.65 dB.

If $f_s = B/2$ (i.e. $2 f_s = B$), the component $f_o - 2 f_s$ attenuated by 18 dB, which introduces a meter error of 0.1 dB.

Finally if $f_s = B$, the attenuation of the $f_o - 2 f_s$ component is greater than 40 dB, and the error in the meter reading is negligible.

9.4. EFFECT OF RIPPLE IN V.C.O. CONTROL VOLTAGE ON ANALYSIS RECORDING AND B.F.O. OUTPUT

Ripple in the external frequency control voltage can produce unwanted modulation of the variable frequency f_v issued by the V.C.O.

The frequency, f_v, is mixed in the first modulator with the incoming signal for analysis ($V_s \sin(2\pi f_s t)$). Sum and difference frequencies are produced. The difference frequency is removed by filtering, see Section 5.3.4. Therefore, only the sum frequency is important, where

$$V_{sum} = V_s \sin(2\pi(f_s + f_v)t)$$

If ripple, V_m, of frequency f_m, is present in the control voltage, side bands are produced in the sum frequency.

$$\begin{aligned} V_{sum} &= V_s \sin(2\pi(f_s + f_v)t) \\ &+ \frac{1}{2} m V_s \sin(2\pi(f_s + (f_v + f_m))t) \\ &+ \frac{1}{2} m V_s \sin(2\pi(f_s + (f_v - f_m))t), \end{aligned}$$

where m is the modulation index

and $$m = \frac{\Delta f}{f_m}$$

The amplitude of the side bands are $\frac{1}{2} m \cdot V_s$

$$\begin{aligned} \frac{1}{2} m &= \frac{1}{2} \frac{\Delta f}{f_m} = \frac{1}{2} \cdot \frac{\sqrt{2}\, V_m\, df/dV}{f_m} \\ &= \frac{V_m}{\sqrt{2}\, f_m} \cdot \frac{df}{dV} \end{aligned}$$

where $\frac{df}{dV}$ = V.C.O. sensitivity.

The maximum permissible ripple voltage, which will produce side bands more than 80 dB below the required signal, can be calculated for different ripple frequencies and scale ranges.

For 80 dB suppression of the side bands $\frac{1}{2}$m must be less than, or equal to, 10^{-4}.

$$\frac{V_m}{\sqrt{2}\, f_m} \cdot \frac{df}{dV} \leqslant 10^{-4}$$

$$V_m \leqslant \frac{\sqrt{2}\, f_m}{df/dV} \cdot 10^{-4}$$

Frequency Scale	Bandwidth (Hz)	Maximum Ripple Voltage	
		f_m = 50 Hz	f_m = 100 Hz
x0.1 lin	3.16 – 10	35 μV	70 μV
- -	31.6	2.2 mV	224 μV
- -	100	35 mV	21.2 mV
x0.1 log	3.16 – 10	5.1 μV	10.2 μV
- -	31.6	315 μV	32 μV
- -	100	5.1 mV	3.1 mV
x1 lin	3.16 – 10	3.5 μV	7 μV
- -	31.6	220 μV	22.4 μV
- -	100	3.5 mV	2.12 mV
x1 log	3.16 – 10	0.51 μV	1.0 μV
- -	31.6	31.5 μV	3.2 μV
- -	100	510 μV	310 μV
x10 lin	3.16 – 10	0.35 μV	0.7 μV
- -	31.6	22 μV	2.24 μV
- -	100	350 μV	212 μV
x10 log	3.16 – 10	0.05 μV	0.1 μV
- -	31.6	3.15 μV	0.32 μV
- -	100	51 μV	31 μV

Table 9.5. Maximum permissible ripple in the Frequency Control Voltage depending on Bandwidth and Frequency Scale

For bandwidths, where the side bands are contained within the filter skirts, the restrictions on ripple voltage are not so great. In this case, the side bands should be at least 10 dB below the filter skirts. Table 9.5 shows the maximum ripple voltages which meet these requirements, in terms of bandwidth and frequency range.

10. SPECIFICATIONS

10.1. MEASURING AMPLIFIER AND FILTER SECTION

Frequency Range:	2 Hz to 200 kHz in three linear and logarithmic ranges.
Pos. x0.1:	2 Hz to 2 kHz.
Pos.x1:	20 Hz to 20 kHz.
Pos. x10:	200 Hz to 200 kHz.

For accuracy of frequency scale, see Section 10.3.

Frequency Response:

Linear Mode:	±0.2 dB (10 Hz to 50 kHz) ±0.5 dB (2 Hz to 200 kHz)
Selective mode:	Six constant bandwidth band-pass filters A, B, C and D weighting networks External filter
Sensitivity:	10 μV to 300 V in 10 dB steps for full scale deflection. Max. 700 V peak on input.

Input Section:

Input Impedance:	1 MΩ//80 pF (direct input) 900 kΩ//80 pF (preamp. input)
Output impedance (to ext.filter):	<25 Ω.
Max. output voltage:	5 V peak

Input amplifier gain:	40 dB (max.)
Gain control:	0 dB (cal) to −10 dB.
Input attenuator range:	90 dB in 10 dB steps. Accuracy of attenuator ±0.1 dB relative to "0.1 V" at 1 kHz.
Distortion:	<0.01% (20 Hz to 50 kHz, output voltage ⩽1 V) <0.03% (20 Hz to 100 kHz, output voltage ⩽1 V)
Noise:	7 μV RMS (max. sensitivity)

Constant Bandwidth Filters:

Type:	Double 2 pole Butterworth.
Effective Noise Bandwidths	
(−3.5 dB)	3.16 Hz, 10 Hz, 31.6 Hz, 100 Hz, 316 Hz and 1000 Hz. 3 dB bandwidth = effective noise bandwidth x0.96.
Accuracy of bandwidths:	±5%.
Shape factor of filter characteristics:	$\frac{BW_{60\ dB}}{BW_{3\ dB}} \leqslant 7$.
Dynamic range:	>85 dB (in bandwidths 3.16 to 100 Hz) >75 dB (in bandwidths 316 and 1000 Hz)

Distortion(input section + filters):	<0.01% (60 Hz to 50 kHz) <0.03% (20 Hz to 100 kHz)
Bandwidth compensation:	Automatic $1/\sqrt{B}$ compensation.

Weighting networks:	Curve A, B and C in accordance with IEC standard (IEC 179). Curve D in accordance with proposed standard.

Output Section:

Input impedance (from ext. filter):	146 kΩ.
Output amplifier gain:	80 dB (max.)
Output attenuator range:	60 dB in 10 dB steps. Accuracy of steps ±0.1 dB relative to the x1 position at 1 kHz.

Recorder Output AC:

Output voltage:	10 V RMS at full deflection (linear meter mode)
Max. voltage:	50 V peak.
Output impedance:	<50 Ω in series with 20 μF.
Load impedance:	⩾12 kΩ.
Frequency of output signal:	30 kHz (316 Hz and 1000 Hz bandwidths) 750 Hz (3.16 to 100 Hz bandwidths) signal frequency in linear and A, B, C, D filter modes.

Recorder Output DC Linear:

Output voltage:	4.5 V at full deflection (equivalent to 10 V RMS AC).
Max. voltage:	15 V.
Dynamic Range:	–50 dB to + 10 dB re full scale deflection.

Crest factor capability:	Up to 5 at full scale deflection decreasing to 1.4 at + 10 dB.
Accuracy of RMS indication:	±0.5 dB for crest factor up to 5.
Linearity of RMS indication:	±0.3 dB in the range −40 dB to 0 dB, and ±0.5 dB over the whole range.
Output impedance:	$<10\ \Omega$.
Load Impedance:	$\geqslant 5\ k\Omega$.
Averaging times:	0.1, 0.3, 1, 3, 10, 30, 100 sec.

Recorder Output DC Logarithmic:

Output voltage:	4.5 V at full deflection (equivalent to 31.6 V AC).
Lin/Log Conversion ratio:	0.9 V (DC)/dB (AC).
Dynamic Range:	−50 dB to 0 dB re 4.5 V.
Crest factor capability:	Up to 5 at −10 dB decreasing to 1.4 at 0 dB.
Accuracy of RMS indication:	±0.5 dB for crest factors up to 5.
Linearity:	±0.5 dB.
Output impedance:	$<10\ \Omega$.
Load impedance:	$\geqslant 5\ k\Omega$.
Averaging times:	0.1, 0.3, 1, 3, 10, 30, 100 sec.

Meter:

Full scale deflection:	10 V RMS at Recorder output (linear), 31.6 V at Recorder output (logarithmic).

Scale range (log mode):	50 dB.
Averaging times:	"Fast" and "Slow" according to IEC 179 and 0.1, 0.3, 1, 3, 10, 30, 100 sec.
Automatic Frequency Control:	Active in the bandwidths 3.16 to 100 Hz.
Pull-in range:	10 Hz to 1 kHz depending on bandwidth and frequency range chosen, see Table 5.5.
Overload indicators:	Indicators for input and output amplifiers. Lamps light for overload pulse longer than 0.2 msec, and remain lit for min. 0.5 secs. Relay output of overload function.
Reference voltage:	
Voltage:	50 mV RMS
Frequency:	1000 Hz sinusoidal
Amplitude stability:	±0.2 dB.
Frequency stability:	±2%.
Distortion:	<2%.
B & T Program:	Automatic switching of bandwidth B and averaging time T. Input socket for external control.

10.2 B.F.O. SECTION

Oscillator:	
Frequency range:	2 Hz to 200 kHz (identical to analyzer).
Accuracy of Output Frequency:	See Frequency Read-Out, section 10.3.

Amplitude Linearity:	±0.2 dB (2 Hz to 200 kHz).
Output voltage:	Attenuator Output: 100 μV to 10 V variable continuously and in 10 dB steps. (Accuracy of steps ±0.1 dB relative to 10 V position). Output impedance is 600 Ω in all attenuator positions. Direct output: 0 to 10 V continuously adjustable. Output impedance 5 Ω. Max. output power: 0.75 W at 140 Ω load.
Distortion: (Load > 600 Ω)	< 0.015% (20 Hz to 50 kHz). < 0.03% (20 Hz to 100 kHz).
Noise:	< −70 dB.
Hum:	< −80 dB.
Compressor Circuit:	
Range of Regulation:	60 dB (compressor voltage within 1 dB).
Frequency Response:	±0.3 dB (2 Hz to 200 kHz).
Compressor Input Voltage:	min. 0.5 V.
Compressor Speed:	3, 10, 30, 100, 300, 1000 dB/sec.
Reference Voltage:	When the button BFO REF. SIGNAL is pressed, the frequency of the BFO output signal is changed to 100 Hz in the "x 0.1" range, to 1 kHz in the "x 1" range and to 10 kHz in the "x 10" range. The output voltage has a level controlled by the BFO ATTENUATOR and BFO OUTPUT VOLTAGE knobs.

10.3 FREQUENCY READ-OUT

Accuracy of Frequency Scale:

Linear scale: 0.3% of scale range.

Logarithmic scale: 3% of reading + 25 ppm of scale range.

Frequency Increment Range:

Linear scale: ±1% of scale range.

Logarithmic: ±7% of scale reading or 0.1 octave.

Frequency Stability: Measured over 8 hours after 1 hour warm-up.

	Low end of scale			High end of scale		
Scale	2 Hz	20 Hz	200 Hz	2 kHz	20 kHz	200 kHz
Lin	0.05 Hz	0.5 Hz	5 Hz	0.5 Hz	5 Hz	50 Hz
Log	0.05 Hz	0.5 Hz	5 Hz	4 Hz	40 Hz	400 Hz

Sensitivity of VCO:

Full scale sweep: 0 to 10 V DC.

Lin Scale x 0.1: 0.2 kHz/V.

Lin scale x 1: 2 kHz/V.

Lin scale x 10: 20 kHz/V.

Log scale: 0.3 decade/V corresponding to 1 octave/V.

Linearity of VCO: 0.03%.

Frequency Counter: Six digits.

Accuracy: ±1 on last digit + 20 ppm of tuning frequency.

Counting time:	0.1 sec (five digits) and 1 sec.
Frequency Marker:	Output for event marker on recorder for exact chart calibration. Activated by change of a preselected digit on Frequency Counter.

10.4 GENERAL

Operating temperature:	10^{o} to 40^{o}C (50^{o} to 104^{o}F).
Power Supply:	100, 115, 127, 150, 220, 240 V (± 10%) 50 to 400 Hz.
Cabinet:	Supplied as model A (light-weight metal cabinet), B (model A in mahogany cabinet) or C (as A but with flanges for standard 19" racks).
Overall Dimensions (A model):	Height: 49 cm (19 in) Width: 38 cm (15 in) Depth: 23 cm (9 in) Weight: 21 kg (46.7 lbs)

Accessories Supplied:

1 AN 0005 (AN 0006)	Power cable and plug. European (American)
2 AO 0013	B & K coaxial cables.
1 AQ 0027	Control cable.
2 JP 0101	Coaxial plugs.
1 JP 0703	7-pin plug.
1 JP 0802	8-pin plug.
1 UB 0041	Flexible drive shaft.
Various lamps and fuses.	

Scales Supplied:

SA 0051	Voltage and dB scale (mounted in the instrument on delivery).
SA 0052	Lin voltage and dB scale.
SA 0053	Log voltage and dB scale.

SA 0055	Power Spectral Density scale (V^2/Hz).
SA 0056	1 inch microphone scale for Sound Pressure Level (SPL).
SA 0057	1/2 inch microphone scale for SPL.
SA 0058	Accelerometer scale. (6 – 17 mV/g).
SA 0059	dB re 1 μV Lin/Log scale.
SA 0087	Uncalibrated scale linear graduation 0 – 100.

Scales Available:

SA 0054	Absorption coefficient scale.
SA 0060	1/4 inch microphone scale for SPL.
SA 0083	1/8 inch microphone scale for SPL.
SA 0084	dB/dBM scale.
SA 0142	Accelerometer scale (1.7 – 6 mV/g)
SA 0143	Accelerometer scale (17 – 60 mV/g)
SA 0144	Accelerometer scale (60 – 170 mV/g)

Scales can be custom made to order.

BRÜEL & KJÆR instruments cover the whole field of sound and vibration measurements. The main groups are:

ACOUSTICAL MEASUREMENTS
Condenser Microphones
Piezoelectric Microphones
Microphone Preamplifiers
Sound Level Meters
Precision Sound Level Meters
Impulse Sound Level Meters
Standing Wave Apparatus
Noise Limit Indicators
Microphone Calibrators

ACOUSTICAL RESPONSE TESTING
Beat Frequency Oscillators
Random Noise Generators
Sine-Random Generators
Artificial Voices
Artificial Ears
Artificial Mastoids
Hearing Aid Test Boxes
Audiometer Calibrators
Telephone Measuring Equipment
Audio Reproduction Test Equipment
Tapping Machines
Turntables

VIBRATION MEASUREMENTS
Accelerometers
Force Transducers
Impedance Heads
Accelerometer Preamplifiers
Vibration Meters
Accelerometer Calibrators
Magnetic Transducers
Capacitive Transducers
Complex Modulus Apparatus

VIBRATION TESTING
Exciter Controls – Sine
Exciter Controls – Sine – Random
Exciter Equalizers, Random or Shock
Exciters
Power Amplifiers
Programmer Units
Stroboscopes

STRAIN MEASUREMENTS
Strain Gauge Apparatus
Multi-point Panels
Automatic Selectors

MEASUREMENT AND ANALYSIS
Voltmeters and Ohmmeters
Deviation Bridges
Measuring Amplifiers
Band-Pass Filter Sets
Frequency Analyzers
Real Time Analyzers
Heterodyne Filters and Analyzers
Psophometer Filters
Statistical Distribution Analyzers

RECORDING
Level Recorders
Frequency Response Tracers
Tape Recorders

DIGITAL EQUIPMENT
Digital Encoder
Digital Clock
Computers
Tape Punchers
Tape Readers

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