L.F. SIGNAL GENERATOR J3B InstructionManual

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GOULD ADVANCE

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2 Introduction

The Gould Advance J3B Signal Generator is an LF instrument incorporating a high output level from a balanced, floating 600 Ω output. The main output, which is metered, gives 15V into 60C Ω (30V EMF). The frequency range of 10Hz to 100kHz is provided on four decade ranges, and the 6: 1 reduction drive with capacitor tuning gives high resolution of frequency with minimum bounce.

Three additional outputs are available, a 1W low impedance output, a square wave output and a low distortion output. The solid state circuitry results in low heat dissipation, giving a high order of frequency stability and reliability.

Switched step attenuators give 60dB of attenuation and the variable level control can be used to provide a further 20dB of attenuation with negligible hum and noise on the output.

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Section1

A7 R2O2 R2O5 R2O5 R2O5 R0 R6 R3 98 R4 8310 R213 R204 R201 R205 #209 R203 R142 R211 R127 R101 A109 R109 P R106 R114 R108 R132 R135 R133 R123 R144 R143 Ri 36 Ri 37 Ri 37 Ri 38 R 72 R 72 R 72 AO/SK 2329 #207 R139 RIQ R1 82 RESISTORS C102 C101 C 10 3 C 13 1 C 7 C 107 C 131 C 131 C 8 C٩ C168 CAPACITORS c ia a C1 C2 C3 C31 TRIO3 TRI34 5199 5118 5148 5165 5165 5165 514 F 511 F 514 F 514 F 516 F SXC 5 6 4 TRIO TRI02 TR133 Ţ. 57 MISC OV DISTORTION O/P 0 2 0 ريميميمين R105 <u>;</u>}© 2 107 A104 ∬m 23. [A126 01 01 01 01 R 18102 TRIO ίĥ (R) ۶Ð J***0 $\mathfrak{O}_{\mathbf{i}}^{\dagger}$ Rg Ţ 810 ∔°" C104 RIDZ SITF T 2 0 0 AMPLIFIER NEGATIVE FEEDBACK CIRCUIT 221 ٤O ⊚₹ Č۲ Tov 8132 50 <u>يالق</u> Æ R Œ \odot SQUARER B123 ď A143 1..... łŀ 10-100EH $\lfloor m \rfloor$ 1-1211 <u>ئ</u> 100 -1 10 - 100 H đ A : * /::: SEF > Towish SKE) EARTH <u>o</u>-3-6 ÷. 5K0)- LOW -2 ľ P 210 SKC)- 100 A π. 5×8)-<u>C.7</u> **]**-[1 ľ 2021 4 5 KA) 200 A • ta d t]. ATTENUATOR 4048 20 WH IN OUT POSITION \$ 2 8 ... SI FRONT PANEL MARKINGS س ،

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Specification

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FREQUENCY

Range:	10Hz to 100kHz in 4 decade ranges.
Scale:	Common 320 ⁰ circular scale for all ranges

Setability: To 1 part in 10⁴ Accuracy: 2% of reading <u>+</u> 1HZ Typically 1% +1HZ

OUTPUTS

 MAIN OUTPUT 30V r.m.s., e.m.f. (15-0-15V) from balanced floating output of impedance 300-0-300 Ohms (15V r.m.s. into 600 Ω load).

Output Impedance tolerance: 5% - Balance 3% Balanced Attenuator: 20dB and 40dB (60dB total).

Accuracy: 0.3dB and 0.5dB respectively, each half. Fine level control, from 0 to full output (Common to Outputs 1,2 and 3).

- LOW IMPEDANCE OUTPUT 3V r.m.s., e.m.f. from approximately 1 Ohm. With Output 1 fully loaded, Output 2 will deliver a typically of 1 Watt into 5 Ohms.
- LOW DISTORTION OUTPUT (at rear of instrument). typically 2.5V r.m.s. from approximately 5k Ω. Overall flatness 0.3 dB.
- 4) SQUARE WAVE, 0 to +5V, independently controlled. Source Impedance approximately 1kΩ. Rise and Fall times better than 1 µs into less than 100pF. Markspace ratio better than 1.1:1.

OUTPUT LEVEL METER

Scaled 0-30V r.m.s. Open Circuit for Output 1. Scale also common to Output 2. Decibel scale, referred to +20dBm into 600 Ω The meter accuracy is 3% of F.S.D.

DISTORTION

1) Outputs 1 &2: less than 0.1% above 100Hz rising to less than 0.5% at 10Hz.

Typically better than 0.05% from 200 Hz to 100kHz

2) Low Distortion Output: Typically better than 0.02% above 200Hz rising to 0.2% at 10Hz.

PROTECTION

All outputs rated for full load simultaneously All outputs Short-Circuit proof, Visible indication of overload on Output Level Meter (Intermittent reading).

SUPPLY VOLTAGE

85-130V and 170-255V 40-400Hz, approximately 20VA. Also 42-52V . DC/300mA Max.

OPERATING TEMPERATURE RANGE:

0^o-50^o. Full specification over range 15^o-35^oC

DIMENSIONS

27 x 27 x 13 cms (10.7 x 10.7 x 7.2 in.)

WEIGHT

6kg (13 lbs.)

NOTE:

All output levels are flat within 1dB over the full frequency range.

Below 30Hz the maximum output level may not be available on full lead, on outputs 1 & 2 (typically 20V available at 10Hz).

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4 Operation

3.1 SWITCHING ON

- (i) Make sure that the voltage supply tap on the transformer is set correctly, and that the correct fuse is used. The transformer is accessible upon removal of the top cover of the instrument. (see 5.1). Unless labelled otherwise, the J3A is delivered for $234V \pm 10\%$ (See Fig. 1 for transformer taps, links and fuse ratings). In addition, an over-voltage tap (41V) is available on the secondary winding, which effectively extends the range of effectively extends the range of supply voltage to -20%.
- (ii) Set the support/carrying handle to the required operating position. The handle is released by pulling both fixing bushes outwards, and it can then be turned to lock in any one of three positions.
- (iii) It is advisable to turn the Output Level Fine control to minimum before switch-on, to avoid large surge outputs for the few seconds that the oscillator takes to stabilise.
- (iv) The Instrument is ready for use half a minute after switching on and fully 'settled' within five minutes. No special precautions with cooling need to be taken normally but natural ventilation should not be restricted when operating at high ambient temperatures.





Figures in brackets refer to use of 41V secondary tap.

3.2 BLOCK DIAGRAM

The broad outlines of the instrument are shown in the block Diagram in Fig. 2. Power is supplied by a Regulated supply which includes the protection circuits. The low distortion output from the Wien bridge oscillator of variable frequency is taken through a front panel Fine Output Level control to

the Power Amplifier, which drives the transformer-coupled power outputs and the Meter circuitry. The same oscillator drives a Squarer, the level being adjustable through a second front panel control.



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Operation

3.3 SELECTION OF FREQUENCY

To set frequency, the Range Switch is turned to the appropriate range. The fine control of Frequency is a circular dial which is set at the desired part of the decade in use. Although the accuracy claimed on the dial calibration is typically 1%, the resolution of the gang capacitor in the oscillator is essentially infinite and frequency can be set to any required value to within 1: 10^4 . It is often convenient to use the independent square wave output to monitor the exact frequency by a Timer Counter.

3.4 BALANCED OUTPUT 15-0-15V r.m.s., e.m.s.,

- (i) Output 1 is mainly intended for making balanced $600 \Omega^{\circ}$ line measurements. In such use the desired amplitude is set on the Meter remembering that half the Open Circuit voltage will appear across the load and the balanced attenuators are used to give $\div 10 \text{ or } \div 100$ facilities.
- (ii) The balanced output can be used *unbalanced*, terminated in 600Ω , in which case Metering and the use of the attenuators is exactly as above. If a low level unbalanced signal from a 600 source is required from the J3A – i.e. less than -40dB – it is advisable to use half the balanced output with the centre tap at the low impedance end, and use a 300 resistor in series externally to make up to 600Ω . This avoids the pickup of small spurious signals due to the unbalance of the output, which can be significant at high attenuation.
- (iii) Half the balanced output can also be used. If terminated with 300Ω , again the Metering and use of attenuators remain unchanged, but of course only half the output voltage is being used, i.e. the output is a quarter of the e.m.f. indicated.
- (iv) In addition, the balanced output can be used in any of the above ways without matched termination, i.e. operated into any load between open and short circuit It would then behave like an e.m.f. with a source impedance of 600 or 300Ω , depending on whether the whole or half the output is used. The attenuators remain operative.
- (v) Finally, there is no reason why different loads should not be used on each half output, remembering that they will be in phase opposition, and the resultants either measured or calculated.
- (vi) The e.m.f. from the bifilar transformer secondaries is essentially balanced. The output resistances at the terminals are balanced to within 3%. Each attenuator may introduce unbalance of 3% in e.m.f., but the unbalance of output impedance remains unchanged, at a maximum of 3%.

Warning:

- 1. The maximum voltage applied between the balanced output and ground must not exceed 500V d.c. or peak a.c.
- 2. The passage of *direct current* through the balanced output must be restricted to less than 50mA, to prevent damage to the output resistors. A much smaller current than this, however, can saturate the output transformers and severely increase distortion. If some d.c. must be passed, it is an advantage to use the attenuators which will effectively reduce the current reaching the transformer by the same ratio. The permissible d.c. is a function of frequency and acceptable distortion, and can best be found by experiment.

3.5 LOW-Z OUTPUT 3V r.m.s., e.m.f. Zo 21 Ohm

(i) This can be used unloaded, and the e.m.f. can be read as 1/10th the Meter reading. The response is flat and the distortion less than at the Balanced Output. The full range of amplitude, i.e. 3V r.m.s., e.m.f., is available when output 2 is loaded by 5 Ω or more, simultaneously with normal loading of output 1.

If output 1 is unloaded and unattenuated, the load on output 2 can be generally reduced to 3Ω at full output.

Loads smaller than 3Ω may cause the protection circuit to operate, unless level is reduced. Under near short circuit conditions the maximum current available from output 2 is approximately 0.9A r.m.s.

Below 30Hz and at full output/loading, the protection circuit may be triggered at the peak of a cycle.

Note When the protection circuit operates because of excessive loading, the output level automatically 'cycles on and off' at intervals of about 2 seconds This is indicated by a corresponding swing on the output Meter.

3.6 LOW DISTORTION OUTPUT 2.5V r.m.s., e.m.f. Z₀≏5k Ohm

- (i) This output, directly from the oscillator, is taken from the slider of the Fine Level Potentiometer through a buffer resistor. It can be loaded without detriment to the performance of the other outputs, although a change of loading reflects on the output levels.
- (ii) An external signal from another Generator can be injected into this output and be resistively mixed with the low distortion J3A signal. The mixed signal is then available at amplified outputs 1 and 2 to permit intermodulation measurements on amplifiers, etc. However, leads left attached to this output can pick up and inject unwanted signals and noise into the J3A.

6 Operation

Section 3

It should be noted that maximum injection occurs with the Fine Level control at its mid setting.

See also 4.2, last paragraph.

3.7 SQUARE OUTPUT 0 to 5V Z ≏1K

- (i) A fraction of the oscillator signal is taken to the Squarer circuit, and the independently controlled output is made available at the front panel as a positive-going square wave from OV (ground). The mark/space ratio and rise and fall times (see Specification) are maintained over the entire frequency range of the J3A. If the mark/space ratio is preset to unity, the square edges 'lag' all the sinusoidal outputs of the generator by approximately 1% of the period + 0.1 us. In the 1 - 10kHz range, however, because of transformer phase shift, the floating output begins to lag the square wave progressively, after approximately 4kHz, by a small amount.
- The square output, being independent in level of all the other outputs, can be conveniently used for Frequency Counting, for externally locking an oscilloscope time base, etc.

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(iii) If terminated in 50 ^Ω, the square wave is reduced to 150mV pk, approximately at full output, and the rise and fall times improve to better than 0.1 u s.

3.8 OUTPUT LEVEL METER & DECIBEL SCALE

- (i) The Meter effectively measures the primary voltage of the output transformers and is calibrated 0 - 30V r.m.s. e.m.f., the total open circuit voltage available at the balanced output. Items 3.4 and 3.5 above describe most of the likely arrangements of load, etc., as well as the use of the matched and balanced Attenuators.
- (ii) The (red) decibel scale is a 'relative' scale to enable amplitude/frequency response measurements to be made conveniently. The OdB point, however, has been chosen to equal +20dBm, for convenience in power measurements in 600 Ω .

3.9 RELATIVE PHASE

The signal out of the left hand terminal of Output 1 with respect to the Centre Tap, is in phase with Outputs 2, 3 and 4 with respect to ground.

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Circuit Description

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4.1 WIEN BRIDGE OSCILLATOR

Transistors, TR1 - TR6, comprise the oscillator amplifier. Transistor TR7, is a supply rail stabiliser.

The input of the amplifier goes to a field effect transistor, TR2, which is in a long-tailed coupling with TR3. TR2 is driven in cascode with TR1, to avoid Miller capacitance to the input gate. The base of TR1 is d.c. coupled to the 'common' emitters of TR2 and TR3, thus providing TR2 with a constant emitter-collector voltage to reduce distortion with the large signal swing at the emitter of TR2 (3Vp-p).

The signal from the collector of TR1 is fed to emitterfollower, TR4, with bypassed collector resistance, R35, serving to limit current at switch-on, before the oscillator d.c. levels are established. Diode D4, from the collector of TR5 to the emitter of TR4, 'catches' the collector of TR5 and prevents it from rising and bottoming by almost the full Zener potential of D2. TR4 drives the base of the transistor TR5, which inverts the signal, feeding it to the output emitter-follower, TR6. From the emitter of TR6 the signal is taken to the input of the Wien Bridge consisting of ganged variable capacitors, C7A, C7B, and the switched Range resistors, R1-R8. The range resistors, R1 to R4, are returned to variable bias at T.P. (A) which sets the d.c. level at the output, T.P. (E). The stability of this d.c. level is maintained by feedback to the base of TR3.

In the symmetrical Wien Bridge configuration used in the J3A oscillator, the voltage transfer of the bridge at 'resonance' is precisely 1/3. A similar voltage transfer is effected in the feedback network comprising Thermistor, R44, its shunt resistors R33 and R34, and the feedback resistor, R30, thus maintaining the high-gain amplifier in operational equilibrium. If the output level is low, Thermistor R44, is cold and hence its resistance is high. This reduces the negative feedback which, in turn increases the gain of the amplifier until equilibrium is re-established. The opposite happens if the output level is high. The same voltage transfer of 1/3 is also a.c. coupled to the resistor, R28 (the 'long tail' of TR2, TR3), effectively producing constant current in R28. The same 1/3 voltage is also applied through buffer resistor, R31, to the 'Guard' T.P. (C), which is connected to guard screens placed around the variable capacitor gang to reduce variations of capacitance between the rotor and ground.

R27, C24, and R37, C30 are frequency roll-off elements to maintain stability and diode, D3, provides signal continuity and circuit stability when TR6 cuts off during the period before the termistor reaches operating temperature and thus reduces output signal level to normal.

The full output of the oscillator from the emitter of TR6, is applied through R9 and C8 to amplitude control, R10, and thence to the Power Amplifier. A tap on the load resistor of TR6 supplies a lower level signal to the input of the Squaring circuit, R46 provides extra current to TR6 to assist "pull-up". The entire oscillator is mounted in a screen box to minimise hum and noise pick-up.

Thermistor R47 compensates for amplitude changes in the oscillator with temperature.

4.2 POWER AMPLIFIER

The power amplifier of the J3A is fed from a regulated rail of +37V and consists of transistors, TR101 – TR106. TR101 and TR102 are connected in a 'long tail' configuration the input signal from the amplitude control, R10, being applied to TR101 and the negative feedback to TR102. The base of TR101 is biased at 1/4 rail voltage via R104 and R102, and the input signal is a.c. coupled through C102. The signal path through the Amplifier is from the collector of TR101 through emitter follower, TR103, and the common-emitter stage, TR104, to the complementary output pair, TR105 and TR106.

There are two negative feedback paths to the base of TR102, via equal resistors, R108 and R120. R120 is connected directly to the output, and R108 is returned to a feedback winding on the output transformer. As this is effectively 'grounded' for d.c., stability is reached when the mean output voltage is twice the base voltage of TR102, that is *half the rail voltage*, enabling the Class B output transistors, TR105 and TR106, to swing equally in both directions.

For signal currents, R108 and R120 are in parallel, since the feedback winding has turns equal to the primary of the output transformer. The negative feedback signal through these resistors develops a voltage across R110+R111, which defines the voltage gain of the Power Amplifier. Bypass capacitor, C106, is large enough not to affect the feedback at the lowest frequency.

Quiescent current for the output transistors, TR105 and TR106, is controlled by transistor TR108 which, together with diodes D103 and D104, is in intimate contact with the heat sink on which the output pair are mounted. When the heat sink temperature begins to rise, TR108 also heats up.¹¹ and as its base- emitter voltage is fixed, it draws increasing emitter-collector current, thus diverting bias current away from the output transistors and restoring equilibrium.

To increase the gain of inverting stage, TR104, and to assist 'pull-down', the load of TR104 is bootstrapped to the output of the amplifier. A tap on the bootstrap through resistors, R116 and R117, provides a voltage approximately equal to the negative feedback at TR102 base, and to this is returned the common emitter resistance of the input pair, TR101 and TR102. As in the oscillator, this technique reduces distortion by maintaining constant signal current in the long tailed pair.

R109 and C104, R107 and C105, R118 and C112, and C113 are frequency roll-off components to maintain stability. Bypassed resistance, R112, limits switch-on surge currents in the amplifier, and D102 prevents hard bottoming of TR104, which could occur while the oscillator amplitude is settling. The input to the amplifier is taken via R101 to a socket at the back of the instrument, thus providing the low distortion amplitude controlled signal directly from the oscillator. An external signal can be *injected* at this point also, to mix resistively with the oscillator waveform, be amplified and become available at the power output of the J3A. The injected signal must be within the frequency range of the output transformer in circuit at any one time.

8 Circuit Description

Section 4

4.3 POWER OUTPUTS

The output of the Power Amplifier is coupled through C116 and a section of the Frequency Switch of the J3A, to the, primary of T1 or T2. These are the Low Frequency and High Frequency output Transformers and operate respectively from 10Hz -10kHz and 10kHz -100kHz. Their feedback and secondary winding are also switched by the Frequency Switch as range is changed.

(i) LOW -Z OUTPUT

A tapping on the primary of each output transformer provides 3V r.m.s., e.m.f., between ground and the Low -Z terminal. The source impedance is approximately 1 Ω permitting about 1 Watt to be delivered into a load of 5 Ohms. The maximum available *current* is approximately 0.9A r.m.s.

(ii) 300-0-300 Ohm OUTPUT

Bifilar wound secondaries on each transformer supply $2 \times 15V$ r.m.s., e.m.f. to the balanced output terminals through balanced attenuators of 20 and 40dB. Separate resistors are brought in by the Frequency Switch to pad the secondaries of both transformers to 300 Ohms each. The respective centre-taps are also switched and the outputs are thoroughly screened.

(iii) A protection circuit will cause the J3A to 'Cycle' on-off this condition being visible on the output meter if an attempt is made to draw excess power from the instrument. In view of its low output resistance excess power is almost invariably drawn from the Low-Z output by a short circuit. The protection circuit will be explained in the section dealing with the Power Supply. (See reference to peak current limiting).

4.4 SQUARE WAVE OUTPUT

As has already been mentioned, a tap on the load resistor of the output of the Wien Bridge Oscillator supplies the input signal to the Squarer. Emitter follower, TR131, further isolates the Oscillator from the Squarer to minimise inter action. The output from TR131 is coupled through C132 to the base of TR132, which, with TR133 forms a Schmitt trigger circuit in which the long-tail current through R134 is switched on-off at the collector of TR133. The output level is controlled by potentiometer, R142, and taken to the output terminal via R139. C133 is a speed-up capacitor to the base of TR133 and preset trimpot, R136, sets the mark-space ratio. R143 is selected on test in parallel with R142 to adjust the output level to be between +5V and +5.5V.

The Squarer is supplied through buffer emitter-follower, TR134, and Zener base reference, D131, to isolate the fast transients from other parts of the J3A. The same Zener D131 after filtering serves as the reference for the Power Supply.

4.5 POWER SUPPLY

Long-tailed pair, TR 161 and TR 162, compare the Zener reference to a fraction of the d.c. output voltage at the slider of trimpot, R 162. The collector of TR 161 conventionally drives compounded series output emitter followers, TR 164 and TR 165, the latter being the main series regulator connected to a heat sink. Zener diode D 162 applies bootstrap feedback from the emitter of TR 165 to R 168, the collector load of TR 161/TR 163, thus presenting a high impedance load and increasing the loop gain.

R169 and C164 are frequency roll-off stability components. The input to the P.S. is provided by the secondary of mains transformer, T3, and Bridge Rectifier, BR161, feeding Reservoir capacitor, C166, whose negative terminal is taken to the 0-volt (ground) line through 1 Ohm, R170.

The protection circuit referred to under Section 4.3 (iii) is composed of R164, a 2.2 Ohm resistor between TR165 and the P.S. output; transistor, TR163; R170; trimpot, R165, and C163. TR163 is connected so that its base-emitter monitors the d.c. voltage drop in R164, its collector being in common with that of control transistor, TR161. Hence, if a current of more than approximately 250mA is taken through R164, TR163 will conduct and reduce the base current available to the series control transistor. This conventional current sensing and limiting alone, would also limit the positive current peaks of the output waveform, especially at the lower frequencies.

While the current overload sensor, TR163, is arranged so that its base is d.c. biased by potential across R164, the a.c. component is balanced out in trimpot, R165, with a fraction of the opposing signal voltage generated across R170 and a.c. coupled via C163. Increasing mean current in R164 causes TR163 to conduct, limiting the drive to TR164 and TR165, thus dropping the output voltage. C163 then, however, discharges through R178 into the base of 1 R163, thus collapsing the supply. In addition, the time constants are such that when the supply collapses on overload, the Wien bridge oscillator is stopped and waits until its control thermistor cools before it can restart. The absence of signal effectively removes the overload from the P.S. which then restores output. The cycle of events continues until the overload is removed or the signal level is turned down. Overload is shown by the Output Level meter cycling on-off at approximately 2 second intervals. A faster 'cycling visible on the Output Level meter generally indicates an internal fault, rather than excessive external loading.

Note: Under certain conditions of overload, the peak current limiting circuitry of the output stage can initiate the 'cycling' of the protection circuit. This situation is most likely to arise when excessive imagnetising current is required by the output transformer, either because of external d.c. magnetisation or through a fault. This initiation of cycling will cause no damage to the instrument.

Circuit Description

4.6 METER CIRCUIT

Equal signals from the output of the P.A. and the feedback winding, supply the germanium diode full wave bridge rectifier through equal resistors, R151 and R152. The resultant d.c. is then set and filtered by R153, R154 and C151. The rectifier is essentially average current, as most of the applied voltage is dropped across the two equal resistors. By monitoring the two points that supply the feedback to the Power Amplifier, the meter circuit is effectively connected to the 'ideal' transformer driving the balanced Outputs, and thus compensates for transformer losses.

4.7 MAINS INPUT

Transformer, T3, is conventionally arranged with a seriesparallel primary and has a single well-screened secondary. The primary is switched and fused, and a Neon indicator is fed from one half primary. (See 3.1 (i) and Fig. 2)

4.8 EXTERNAL D.C. SUPPLY

Two coded sockets at the back of the instrument permit operation from a FLOATING D.C. supply of 40-48V. Current at maximum output and loading is approx. 250mA. A diode, internally, protects against incorrect polarity of the external supply.

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10 Maintenance

5.1 REMOVAL OF COVERS

Warning: Take care not to touch the supply transformer or fuse with the supply ON.

To remove the covers from the instrument, firstly remove the bottom by unscrewing the 4 retaining screws. Then by gently pulling the side panels outwards the cover should lift off. It will generally be found more convenient to carry out adjustments or repairs with the bottom of the instrument upwards and to use an external supply (See 4B) for testing and calibration.

5.2 REMOVAL OF OSCILLATOR BOX COVER

This is held on by seven screws, 4 at the bottom and 3 at the top, all 7 screws working in slots. After undoing each screw by about 3 turns, the cover can be slid out. Refitting is a reversal of the above procedure, being careful to butt the cover well against the steel oscillator box when tightening the screws.

REMOVAL OF PRINTED CIRCUIT BOARD 5.3 ASSEMBLIES

- (i) Removal of Oscillator P.C.B. (Fig. 4) This is released by undoing 4 screws, as shown in the figure. Then the yellow lead on the underside of the board to pin 'C' (Guard) is unsoldered. The board is now free and can be eased out and swivelled about the cables and leads going to the Range Switch.
- Release of Master P.C.B. (ii)
 - Remove 4 screws securing rear panel. Disconnect (a) the 2 leads from the Low Distortion terminals.
 - (b) Undo the two screws that hold the board to the bracket near the Mains transformer.
 - (c)Disconnect the two brackets that support the board to the case (top and bottom) towards the middle of the P.C.B.
 - (d) Remove the top screw securing the output transistors' heat sink to the side member, near the two large electrolytics mounted on the board. Slacken the corresponding bottom screw securing the heat sink. The board can now be swivelled against the cables and harness to remove damaged components, although many of these are accessible simply by removing the rear panel.

Note: Complete removal of the P.C.B.'s requires disconnection of all leads, which should be clearly labelled for correct reconnection.

SETTING UP OF WIEN BRIDGE OSCILLATOR 5.4

- Work which is possible with cover removed. (i)The cover should not be removed unless a fault exists in the oscillator board.
 - Turn Fine Output Control to minimum. 1.
 - 2. Disconnect coax. lead from Point D (to squarer)
 - Check incoming +37V rail at check position on 3 switch, or on master P.C.B. (red leads). If faulty, disconnect the oscillator from +37V rail and use an external +37V supply rated at 50mA to supply the oscillator.
 - 4. Connect an a.c. coupled oscilloscope (1V/div., 0.1 mS/div.) to 'Oscil. Test Point' as shown in Fig. 4 (On the middle switch wafer outside the oscillator box).

- Set frequency to approximately 3kHz, and 5. switch on,
- 6. If there is no fault, oscillations should build up die out, restart and stabilise.
- Connect D.V.M. or 20k ΩV Voltmeter, 7 across C25, Trim R22 for a reading of 12.5-13V Examine the waveform on the oscilloscope for possible clipping, etc. It should be clean.
- 8. Trim R34 for 8v p-p on the oscilloscope. Restore wiring to normal.

(ii) Work with cover in position:

(In the absence of a fault, begin setting up here) Step 7 above may be carried out by connecting a d.c. Voltmeter to 'Oscil. Test Point').

- Connect the a.c. high impedance Voltmeter to 1. 'Oscil. Test Point' replacing the oscilloscope. The Voltmeter should be calibrated to 1% at 2.8V r.m.s., and have a flat frequency response from 10Hz to 100kHz, inclusive of the screened cable connector.
- 2. Connect the Frequency counter to the Squarer output. Set this to a convenient level.
- 3 Select the 1-10kHz Range, and set the dial to 1kHz. Note the frequency on the counter.
- 4. Trim R34 for 2.8V r.m.s. on the Voltmeter and tune towards the high frequency end of scale, carefully observing the voltmeter reading. If the Wien bridge is trimmed correctly, the reading should stay constant at 2.8V.
- Set the dial to 10kHz and trim C2 and C3 to 5. obtain ten times the frequency noted in step 3 above. Note that increasing C2 and/or C3, decreases the frequency, and that increasing C2 and decreasing C3, can keep the frequency constant while decreasing the output of the oscillator. The two trimmers should be set for the right frequency and least amplitude variation over the range. Note the amplitude at 10kHz.
- Reset 1kHz on the counter. Slacken the two grub 6. screws that hold the tuning gang spindle in the epicyclic drive and reposition the scale to agree with the counter.
- 7. Set the dial to 10kHz and trim frequency to agree, with amplitude retained at that giving least variation over the band. (Step 5.)
- 8. Check frequency/dial agreement on 100-1000Hz and 10-100kHz ranges at various points, and if necessary, reset the dial (repeating Steps 6 and 7) for minimum frequency error overall. If the error approaches 2% a fault in the appropriate range resistors should be suspected, or else in the gang.

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- Check 10-100Hz range, allowing for the +1Hz 9. tolerance in the specification. The oscillator should now be set and be flat within 0.3dB.
- 10. Finally, return to the 1-10kHz Range at 9kHz setting, note frequency reading and 'rock' the tuning knob whilst adjusting C2 and C3 for minimum amplitude bounce. Check that the noted frequency reading has been held unaltered.

It should be noted that clockwise dial rotation producing amplitude increase requires increase (frequency lowering) of the Trimmer C3 nearest the edge of the oscillator box (grounded trimmer).

Conversely, C2 has the opposite effect.

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Maintenance

Note: A piece of insulated wire is wrapped around the highest range resistor R8 shunting it by approx. 1/4pF This raises the frequency at the top end of the highest range by 1% approx., to produce closer agreement with the scale.

5.5 SETTING UP OF POWER SUPPLY

Note: All trim potentiometers on Master P.C.B. can be adjusted from the back of the board through suitable holes.

- 1. Turn the level control to zero.
- Adjust R162 for +37V ± 0.5V at pin +'37V' carrying red lead.
- 3. Provisionally set R165 at its mid setting. *After* adjusting the Power Amplifier, the frequency is
- Skhz_set to 390Hz and a.c. coupled and floating millivoltmeters is connected between +37V point and the slider of R165, to test point marked "SET NULL". The P.A should be loaded with approximately 5 Ohms at the Low -Z tap, the 40dB attenuator engaged to load the balanced output, and the Level control should then be advanced and R165 adjusted, for minimum signal on the voltmeter while increasing level to maximum. The adjustment is eased if the oscilloscope Timebase is set to 1 m s/div. and 'free run', in which case the 3kHz signal appear as a multiple trace whose width should be reduced to a minimum. If the protection circuit operates, switch off and check R164 and R170. The minimum unbalance signal is generally less than 1 millivolt.
- 4. Check that, at the nominal mains voltage for the transformer tap in use, the reading between the collector of TR165 (heat sink) and ground, is not less than +44V under load as in Step 3 above.

5.6 SETTING UP THE POWER AMPLIFIER

(i) Quiescent Current of Output Stage.

- Set the Level control to zero and remove the loading from the instrument. Switch out the attenuator.
- 2. Switch off and disconnect the link between the collector of TR106 and ground (Fig. 4) The link is at the bottom rear right corner of the instrument, near a large electrolytic. Replace the link by a d.c.milli-ammeter (-ve to ground) and solder a capacitor of value 0.5 to 1 μF across the link pins. R129 is adjusted to give a quiescent current in the output pair of 18-30mA. It should be noted that current through R130 modifies the behaviour of TR108 (see 4.2, para. 4) so that quiescent current is slightly reduced with increased heat sink temperature, caused by running at full load over long periods.
- 3. Switch off and restore circuit link.
- (ii) Check the output d.c. devel between ground and the +ve end of C114 (See Fig. 4). It should be within 1 volt of *half* the supply rail. If not, check R102 R104, R108, R120 and C106 for leakage.

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5.7 SETTING UP SQUARER

- (i) Connect the oscilloscope to Square Output, 1V/div., 0.1ms/div.
- Select Range 1-10kHz and a frequency of 1kHz, so that 1 cycle (square) occupies exactly 10 oscilloscope divisions.
- (iii) Trim R136 for mark/space ratio of unity.
- (iv) Change the polarity of trigger on the oscilloscope and retrim, if necessary, so that the transition of the square wave occurs at the same point on the oscilloscope, near the 0.5ms centre. This should eleminate possible oscilloscope nonlinearity.
- (v) Verify that amplitude is within specification. If excessive, suitably shunt front panel control R142 (1k Ω) by A.O.T. resistor, R143 across the pins at the output of the squarer projecting from the track side of the PCB. Should the output be less than specified, check D131 (24V Zener), R142, R132, R133 and R134, in this order.
- (vi) Confirm that rise and fall times are within specification. If not, check R135 and C133.

5.8 DISTORTION (See Fig. 3)

- (i) If the preceding adjustments have been carried out correctly, distortion should be well within specification Apart from obviously faulty circuitry, the following is a short check list of the more likely causes of excessive distortion, if the instrument is functioning in other respects. If available, a Distortion Factor Meter is invaluable in tracking down distortion, particularly if possessing an output giving residual component frequencies after cancellation of the fundamental.
 - Change of component parameters could cause short burst of high frequency oscillation at some specific point of the signal cycle, as seen on an oscilloscope, particularly immediately after switching on when oscillator amplitude is still unstablised. When the J3.B with this form of distortion is used as a signal source, it will generally result in 'noisy' or flickering measurements.
 - 2. Cross-over distortion in the power output stage, generally due to failure or error in the bias components (see section 5.7 i) or damaged output transistors.
 - Supply hum or signal ripple across the 37V rail, caused by power supply failure or damaged electrolytic, C115. At full loading, the total supply + signal ripple across C115, should not exceed 40-50 mV p-p.
 - Square Wave break-through, caused by failure of TR131 or TR134.
 - 5. If the distortion output gives predominantly 3rd harmonic at 10kHz, higher than the value specified, with corresponding increases of distortion at lower frequencies, suspect a faulty stabilising Thermistor in the oscillator.

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- (ii) Any failure or error in the feedback paths (including Switching) in the P.A., or wrongly set protection and limiting circuits in the P.S., can cause large distortion, increasing with output level.
- (iii) If the distortion increases with output level beyond the specified limits then the fault is with the P.A. If the fault is in the oscillator, then distortion is sensibly independent of level at all outputs.

Fig. 3 Graph of Distortion and Frequency



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ABBREVIATIONS USED FOR COMPONENT DESCRIPTIONS

RESISTORS				
CC	Carbon Composition	%W	10%	unless otherwise stated
CF	Carbon Film	1/8W	5%	unless otherwise stated
MO	Metal Oxide	1/2W	2%	unless otherwise stated
MF	Metal Film	WW	1%	unless otherwise stated
ww	Wire Wound	6W	5%	unless otherwise stated
СР	Control Potentiometer		20%	unless otherwise stated
РСР	Preset Potentiometer MPD PC		20%	unless otherwise stated
CAPACITORS				
CE(1)	Ceramic		+ 80%	
			- 25%	
CE(2)	Ceramic	500V	+ 10%	unless otherwise stated
SM	Silver Mica			
PF	Plastic Film		+ 10%	unless otherwise stated
PS	Polystyrene			
PE	Polyester		+ 10%	unless otherwise stated
PC	Polycarbonate		-	
E	Electrolytic (aluminium)		+ 50%	
	-		- 10%	
Т	Tantalum		+ 50%	
			- 10%	

NOTE: Components coded on the master PCB in YELLOW are not used.

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Circuit Ref.	Value	Description	Tolerance %		Part No.
RESISTORS					
D1	30M	MF	<u>+</u> 1		32772
	2M	ME	+0.5		32773
RZ	200K		+0.5		32774
R3 .	20V		+0.5		32775
R4	JUK		+1		32772
R5	30M		<u>+</u> 05		32773
R6	3M	MF	<u>+0.5</u>		32774
R7	300K	MF	<u>+0.5</u>		22775
R8	30K	MF	<u>+</u> 0.5	4 (0)	32775
R9	270	CF	<u>+</u> 5	1/8W	20/20
R10	5K	Ср	. =		A4/32606
R11	47K	CF	<u>+</u> 5	1/8W	21815
R21	100K	CF	<u>+</u> 5	1/8W	21819
R22	25K	PCP			29602
B23	47K	CF	<u>+</u> 5	1/8W	21815
R24	1K	CF	<u>+</u> 5	1/8W	21799
D25	15K	CE	<u>+</u> 5	1/8W	28727
R25	5K6	CF	+5	1/8W	21806
R20	560	CE	+5	1/8W	21798
R27		CE	+5	1/8W	28725
R28	168		+2	.,	28790
R29	750	MO	 +2		26740
R30	390		 +5	1/8\//	21802
R31	2K2		+2	1/010	26733
R32	1K5	MO	+2		27346
R33	820	MO	<u>'</u> 4		28969
R34	2K5	CP	±6	1 /014/	21810
R35	12K	CF	<u>+</u> 5	1/8₩	28721
R36	330	CF	<u>+</u> 5	1/8W	20721
R37	180	CF	<u>+</u> 5	1/8W	21795
R38	1K8	CF	<u>+</u> 5	1/8W	28725
R39	680	CF	<u>+</u> 5	1/8W	28723
R40	1K	CF	<u>+5</u>	1/8W	21/99
R41	33K	CF	<u>+5</u>	1/8W	21814
R42	100	CF	<u>+</u> 5	1/8W	21794
R43	2K7	CF	<u>+</u> 5	1/8W	28726
B44	1.9V/1ma Wkg.	Thermistor R15		3mW S	SELECTED 32421
R45	330	CF	<u>+</u> 5	1/8W	28721
846	3K9	CF	<u>+</u> 5	1/8W	21804
847	1K8/25% Thermister	r BP152CY	10%	1/4 W	35712
P 101	4K7	CF	+5	1/8W	21805
9102	33K	CF	+5	1/8W	21814
R102	351	0.	_		
R 103	1001	CF	+5	1/8W	21819
R104	CK0	CE	+5	1/8W	21807
R105	010	CE	+5	1/8W	21803
R106	3K3		+5	1/8W	28717
R107	82	~~	+2	1/8%/	28805
R108	16K	MU	<u> </u>	1/011	20000
R109	820	CF	<u>.</u> ,		20/24
R110	330	CF	±2	1 /0\4/	20/41
R111	2K7	MO	<u> </u>	1/011	20/20
R112	8K2	CF	<u>T</u> 9	1/04/	21808
R113	68	CF	<u>T</u> 0	1/8₩	28716
R114	330	CF	<u>+</u> 5	1/8W	28/21
R115	1 [′] K	CF	<u>+</u> 5	1/8W	21799
R116	270	CF	<u>+</u> 5	1/8W	28720

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Circuit Ref.	Value	Description	Tolerance %			Part No.
RESISTORS (Con't)						
			. T	1 /014/		28718
R117	120	CF	<u>+</u> 5	1/8W		20710
R118	56	CF	<u>+</u> 5			28/15
R119	1K5	CF)	+5	1/8W	A.O.T.	21801
B120	16K	MO	+2			28805
R120	1	MAAA	_			34200
RIZI	1	VV VV		1/8W		34200
R122	1	ww	+5	1,011		28721
R123	330	CF	<u> </u>	4 /OIA/		2180/
R124	2R2	WW		1/044		31034
R125						
B126						
B127	470	CF	<u>+</u> 5	1/8W		21/9/
0100	220	CE	<u>+</u> 5	1/2W		18524
D100	11/					32523
R129	154	CE	<u>+</u> 5	1/8W		28727
R 130	121	CE	+5	1/8W		21810
R [3]			+5	1/8W		28727
R132	IDK		 + 5	1/81/		21808
R133	8K2	CF	<u>-</u> 5	1/044	• • T	26729
R134	2K7	MO	<u>+</u> 0	1/8W	A.U. I.	20720
R135	150	CF	<u>+</u> 5	1/8W		28/19
R136	2K5	РСР				28969
D107	15K	CF	<u>+</u> 5	1/8W		2872 7
R137	942	CE	+5	1/8W		21808
R138	052		+5	1/8W/		21797
R139	470		<u> </u>	1/014/		21802
R140	2K2	CF	<u>+</u> 0	1/01		21002
R141	12K	CF	<u>+</u> 5	1/8W		21010
R142	1K	СР				A4/32607
8143		CF	<u>+</u> 5	1/8W	A.O.T.	
PIAA (EITTED IN	561	CE	<u>+</u> 5	1/8W		28715
	202	10/10/	+5	21⁄2W		31894
RI45 PLACE OF		05	+5	1/8W		21809
R151 SELIQLINK.	IUK	CF	 +5	1/91/		21809
R152	10K	CF	<u>_</u> 5	1/044		29060
R153	2K5	СР				20909
R154	1K5	CF	<u>+</u> 5	1/8W		21801
D 4 0 4	104	CE.	+5	1/8W		21810
R161				1/011		28970
R162	5K	PCP	+ 5	4 /014		21912
R163	22K	CF	<u>-</u> 0	1/011		242012
R164	2R2	CF				34201
B165	5K	PCP				28970
B166	22К	CE	<u>+</u> 5	1/8W		21812
R167	282	CE	+5	1/8W		34201
R167	CK9	CE.	+5	1/81		21807
R168	668		+5	1/014/		28716
R169	68	CF	<u>+</u> 5	1/844		24200
R170	1	WW				34200
R171	470	CF	<u>+</u>	1/8W		21797
R174	1-10M	AOT				
R178	1K2	CF	<u>+</u> 5	1/8W		21800
	1 400	A45	+1			32776
R201	1480	ME	<u></u> 1 			32777
R202	15K	MF				22776
R203	1480	MF	<u>+</u>			22770
R204	15K	MF	<i>는</i>]			32///
R205	367	MF	<u>+</u> 1			32/18
B206	306	MF	<u>+</u> 1			32779
P207	367	ME	+1			32778
n207	2007	ME	+1			32779
H208	300		<u> </u>			32778
R209	367	ME	<u>+</u> 1 + 1			2770
R210	306	MF-	<u>_</u> 1			32//9
R211	367	MF	<u>+</u>]			32778
R212	306	MF	<u>+</u> 1			32779

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Circuit Ref.	Value	Description	Tolerance %	I	Part No.
RESISTORS (Con't)					
8221	0868	CE	+5		31888
0000	280	0, MC	+1		32826
R222	280	MIF	<u> </u>		22020
H223	280	MF	<u> </u>		32820
R224	187	MF	<u>+</u> 1		29471
R225	187	MF	<u>+</u> 1		29471
CAPACITORS					
C1					
C2	6/25pF	Trimmer			23593
C3	6/25pF	Trimmer		i.	23593
0.7	510-5				
C7	518pr +518pF			С7А + С7В	33999
C8	68µF	ε	,	16V	32174
C9	1.5oF	S/M			813
00 00	150 5	с,		161/	32175
021		C		350)/	35607
C22	0.22μ-	PE		250 V	00007
C23	68µF	E		6.3V	32162
C24	68pF	CE(2)	<u>+</u> 10	500V	22374·
C25	1000µF	E		16V	32178
020	5 6oF	CE(1)		500V	22361
C26	5.00F	52(1) E		161/	32175
C27	15045	с г		0.01	22164
C28	470µF	E 05(4)		6.3 V	32104
C29	.01µF	CE(1)		250V	22395
C30	33pF	CE(2)	<u>+</u> 10	500V	22370
C31	470µF	E		40∨	32191
C32	47µF	E		40V	32188
C101	0.22uE	PF			31379
C101	22.5	5		25\/	37181
0102				254	22261
C103	5.60F			5007	22301
C104	56pF	CE(2)		500V	223/3
C105	680pF	CE(2)	<u>+</u> 10	500V	22385
C106	150µF	E		16V	32175
C107	82pF	CE(2)		500V	22375
C108	470uF	E		6.3V	32164
C109	01. E	CE(1)		2501/	22305
C110	E Co E			5001/	22330
	560F			5000	223/3
CIII	470µF	E		6.3V	32104
C112	56pF	CE(2)		500V	22373
C113	5.6pF	CE(2)		. 500V	22361
C114	330µF	Ε		16V	33998
C115	2200 <i>µ</i> F	E		40V	31844
C116	2200µF	E		257	32520
0117	10045	c		414	34004
0121	1.5			4V 201/	26700
0131	. 1 µF			JUV	30/08
0132	25µr			25V	32101
C133	33µF	t		500V	223/0
C134	47# F	E		25∨	32182
C135	560 pF	CE			22384
C151	47µ F	E		10V	32167
C161	22.15	c		101/	22122
0160	33µ1?	с г		107	321/3
	4/µF	E		25V	32182
C163	47µF	5		63V	32199

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Circuit Ref.		Value	Descriptio	n	Tolerance	%		Part No.
CAPACITORS (Con't)								
C164		2200pF	CE(2)		<u>+</u> 10		500V	22389
C166 C167 C168		1000µF .047µF 560pE	E CE(1)		+40 -20		63∨	32521 19657
			UE(2)	·	-20		500V	22384
TRANSISTOP	RS							
TR1 TR2 TR3 TR4 TR5 TR6 TR7			2N3904 AE15 2N3904 2N3906 2N3906 2N3906 BC107					24146 A32067 24146 21533 21533 21533 26790
TR101 TR102 TR103 TR104 TR105 TR106 TR106	NOT LITT		2N3904 2N3904 2N3906 BCY70 2N6179 2N6181					24146 24146 21533 23354 34330 34331
TR107 TR108 TR131 TR132 TR133 TR134			BC209 BC209 2N3906 2N3906 2N3904	M	FOR S AURITRO	ERVICE CONTA N TECHN w.mauritr	MANUALS CT: ICAL SERVICES	33331 33331 21533 21533 24146
TR161 TR162 TR163 TR164 TR165			2N3904 2N3904 BC209 BC107 2N5296		TEL FAX	: 01844 (: 01844	- 351694 - 352554	24146 24146 33331 26790 28630
DIODES								
D1 D2 D3 D4		5V6 5V6	1N4148 1N4148					4109 4109 23802 23802
D101 D102 D103 D104 D105		5V6	1N4148 1N4003 1N4003 1N4148	MOTOR	DLA ONLY			4109 23802 32771 32771 23802
D131		24∨						22175
D151 D152 D153 D154 D161 D162			AAZ13 AAZ13 AAZ13 AAZ13 1N4003					4472 4472 4472 4472 2346 2 33925
D162		3V9	IN4148					23802

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Circuit Ref.	Value	Description	Tolerance %	Part No.
MISCELLANEOU	S			
L1		Choke		A4/32781
MR 161		W02		19725
T1		Transformer	L F,O/P	A1/32590
Τ2		Transformer	H.F.O/P	A1/32591
T 3		Transformer	Supply	34891
FS1	250mA	Fuse	SLO-BLO	1898
N1		Neon		31870
S1		Switch(Range)		34466
S2		Switch(P.B.)		32604
S3		Switch(Rocker)		32612
ME1		Sifam Type 23		A3/32600
SKA		Terminal Guest	Type TP2/4mm (Red)	30137
SKB		Terminal Guest	Type TP2/4mm (Black)	35719
SKC		Terminal Guest	Type TP2/4mm (Red)	30137
SKD		Terminal Guest	Type TP2/4mm (Red)	30137
SKE		Terminal Guest	Type TP2/4mm (Green)	32735
SKF		Terminal Guest	Type TP2/4mm (Red)	30137
SKG		Terminal Guest	Type TP2/4mm (Red)	23635
SKH		Terminal Guest	Type TP2/4mm (Black)	23636

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Guarantee and Service Facilities

Section 7

AMENDMENT GUARANTEE

This guarantee supersedes the existing guarantee shown in this handbook.

This instrument is guaranteed for a period of two years from its delivery to the purchaser, covering faulty workmanship and replacement of defective parts other than cathode ray tubes and batteries (where fitted). Cathode ray tubes are subject to the manufacturers guarantee. This assumes fair wear and tear and usage in the specified environment and does not cover routine recalibrations and mechanical adjustments.

We maintain comprehensive after sales facilities and the instrument should be returned to our factory for servicing if this is necessary. The type and serial number of the instrument should always be quoted, together with full details of any fault and service required.

Equipment returned for servicing must be adequately

Service Dept., Roebuck Road, Hainault, Essex, IG6 3UE Tel: 01-500 1000 Telex: 263785 Telegrams: Attenuate Ilford packed, preferably in the box in which the instrument was supplied and shipped with transportation charges prepaid. We accept no responsibility for instruments arriving damaged. Should the cause of failure during the guarantee period be due to misuse or abuse of the instrument, or if the guarantee has expired the repair will be put in hand without delay and charged unless other instructions are received.

Our Sales, Service and Engineering Departments are ready to assist you at all times.

The Service Department can provide maintenance and repair information by telephone or letter, if required.

Note: Please check fuses before returning instruments for service.

Section 6

		Oscillat Measu Check
		T ₃
		TR16 HEAT S
		C166 —
		С7А,В (
		GUARD
		R5 to R8
		R34 SET 2-8
		THERM
	FOR SERVICE MANUALS	CHECK
1	CONTACT: MAURITRON TECHNICAL SERVICES www.mauritron.co.uk	R1 to R4
	TEL: 01844 - 351694 FAX: 01844 - 352554	OSCILL/ ASS
		R22 SET 12 ^{.5}

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Fig. 4 Component Location Diagram



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Section 6



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22 Guarantee and Service Facilities

This instrument is guaranteed for a period of one year from its delivery to the purchaser, covering the replacement of defective parts other than tubes, semiconductors and fuses. Tubes and semiconductors are subject to the manufacturers' guarantee.

We maintain comprehensive after sales facilities and the instrument can, if necessary, be returned to our factory for servicing. The type and serial number of the instrument should always be quoted, together with full details of any fault and the service required. The Service Department can also provide maintenance and repair information by telephone or letter.

Equipment returned to us for servicing must be adequately packed, preferably in the special box supplied, and shipped with transportation charges prepaid. We can accept no responsibility for instruments arriving damaged. Should the cause of failure during the guarantee period be due to misuse or abuse of the instrument, or if the guarantee has expired the repair will be put in hand without delay and charged unless other instructions are received.

OUR SALES, SERVICE AND ENGINEERING DEPARTMENTS ARE READY TO ASSIST YOU AT ALL TIMES.

Service Dept., Roebuck Road, Hainault, Essex. Tel: 01-500 1000

Manual Part No. 37858

FOR SERVICE MANUALS CONTACT: MAURITRON TECHNICAL SERVICES www.mauritron.co.uk TEL: 01844 - 351694 FAX: 01844 - 352554

Section 7