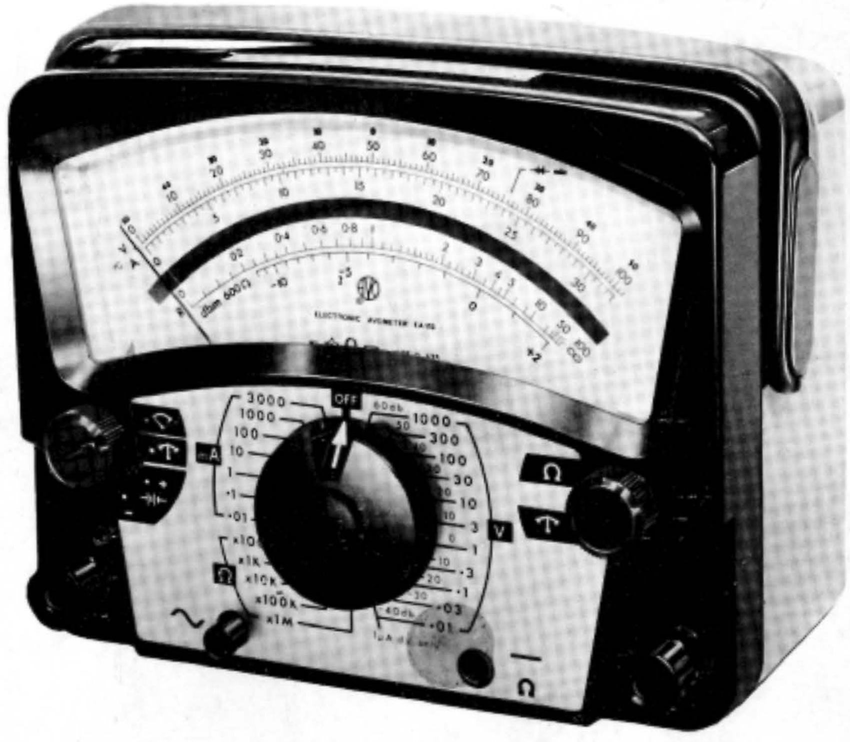
SERVICING INFORMATION

ELECTRONIC AVOMETER
TYPE EA 113



SERVICING INFORMATION

ELECTRONIC AVOMETER TYPE EA 113

These instructions have been written to provide a general guide to the servicing of the Electronic Avometer EA 113.

No attempt should be made to service this Avometer unless the full range of recommended test equipment as shown on Pages 6 and 7 is available.

In the event of a major overhaul the instrument should be returned to Avo Limited or to the representative in your territory.

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SERVICING INFORMATION

INTRODUCTION

For almost fifty years the Avometer has built for itself an unrivalled reputation for reliability and service. It is, however, inevitable that instruments fail from time to time, mainly due to accidental misuse, and when they do, it is essential that they are repaired to the highest possible standard. This booklet has been produced therefore to aid our customers and associates, both at home and overseas, and it is hoped that it will form a useful guide to the trained engineer who has the task of servicing our products. The instrument has not been dealt with in absolute detail, for to do so, would be beyond the scope of this publication, although it is assumed that the engineer undertaking the work has a good knowledge of the principles of moving coil multi-range measuring instruments and electronics.

The instrument has been 'broken down' in such a manner that an engineer with suitable tools and test gear, can take Avo components and spare parts and fit them into the instrument, which will then only require a minimum degree of calibration and test.

Particular note should be taken of the advice which is given regarding the use of complete sub-assemblies. It is advisable to keep a number of key items in stock, in order that they can be immediately available when required. A faulty movement can be returned to the factory and an allowance will be made for serviceable component parts.

No attempt should be made to service an Avometer unless the full range of recommended test equipment, is available. In the event of a major overhaul the instrument should be returned to the Avo representative in your territory.

TEST FACILITIES AND EQUIPMENT REQUIRED

1. ESSENTIAL TEST FACILITIES, EQUIPMENT AND CONDITIONS

Certain facilities and equipment are absolutely essential before any consideration can be given to the possibility of undertaking the repair of the electronic Avometer. To assist in deciding whether the facilities and equipment are adequate, a list of tools and test gear which will form the minimum requirements is given below. If it is decided to undertake the more complicated tasks then very much more equipment will be required. For certain operations, good sight and a steady hand are essential.

The room in which repairs are to be carried out should preferably have air filtering and be temperature controlled. The bench tops should be covered with plain light coloured linoleum or similar material. Good daylight, but shielded from direct sunlight is satisfactory, but in any case it should be supplemented for certain operations by light from tungsten lamps with suitable shades. Care should be taken not to create dazzle or excessive lighting contrast and it is suggested that when dependent on artificial lighting, a general bench illumination of 75 lumens per square foot (ft. candles) is satisfactory. Do not smoke - this is particularly important when inflammable or cleaning fluids are exposed.

INSTRUMENTS AND TEST GEAR

Suitable precision voltmeters a.c. and d.c.)
Suitable precision ammeters a.c. and d.c.) Avo Digital System or equivalent.
Suitable precision ohmmeters)
F.E.T. Test Gear No. 467 (drg. No. A6170-018 available to construct)
Dual Power Supply $\pm$ 2.3V to $\pm$ 3.4V.
Audio Oscillator with 1V output
Electronic Avometer EA 113 (spare)
D.C. Calibrator (Bradley 123B or equivalent)
Controlled Voltage & Current Supplies (Avo Test Console & Extension Box T670A or equivalent.)
A.C. Calibrator (Hewlett Packard 746A or equivalent.)
High Voltage Amplifier (Hewlett Packard 746A or equivalent.)
Mallory Duracell ZM9 1.4V batteries
A substitute movement encased and with flying leads
Flash testing equipment
Microscope with 16mm objective and X10 or X15 eyepiece
Thermometer
Draught proof box with mountings for movement and having a glass cover and connections for test purposes.
Avo Magnetising Unit.
Avo Transistor Test Set Type TT.166. (or equivalent)

TOOLS AND OTHER AIDS

Movement Assembly Jig Avo Part No. AF5075
De-soldering equipment with solder removal facilities
A small soldering iron
Lightweight soldering iron for movement repairs
Screwdrivers for 2BA, 4BA, and 6BA screws
Torque screwdriver 8BA 3 to 4 in. lb.
A set of watchmaker's screwdrivers
A set of BA box spanners
5/16 in. BSF box spanner
A set of open-ended BA spanners
Tweezers suitable for light work on moving coil hairsprings, etc.
Pliers, various sizes
A pair of circlip pliers
A pair of side cutters
A hand drill
A set of twist drills from $\frac{1}{4}$ in. diameter (6mm) approximately downwards
One each of the following taps: 2BA, 4BA, 6BA, 8BA and tap wrench
A pin or tack hammer
Pencil brushes
$\frac{1}{2}$ in. brushes
An eye glass
Bellows or air blast

SPARE PARTS

A stock of Electronic Avometer Spares
A stock of recently manufactured appropriate cells
A stock of appropriate electronic components

MISCELLANEOUS ITEMS

Some small receptacles to hold piece parts
Small glass jars with lids for fluids containing methylated spirit, switch cleaning fluids such as Carbon Tetrachloride or Electrolube and degreasers such as Trichlorethylene or Genklene
A reel of good quality cored solder (60% tin, 40% lead) in 16 s.w.g. or 1.5mm such as 'Ersin Multicore'
A reel of good quality solid solder wire (60% tin, 40% lead) in 20 s.w.g. or 1mm for soldering hairsprings
Tinned copper wire 18 s.w.g. and 22 s.w.g.
Sleeving for tinned copper wire
Some small sticks of orange wood
A bundle of pith or clean cork
A number of steel needles
A mapping pen and Indian ink
Tubes of adhesive such as Bostik Type 299 White
Tubes of Bostik Black or similar glazing compound
Vaseline or similar grease
LOCTITE retaining compound (Green)
Wash leather
Cleaning cloths.

2. SUGGESTED REPAIR PROCEDURE

When the instrument arrives for repair, examine it carefully and note any signs of damage which might have been caused whilst the instrument was in the course of transit. Apart from internal inspection, do not proceed with any repairs until, (a) the customer's observations regarding the failure of the instrument have been received and, (b) it is certain that the instrument has not suffered damage in transit. Severe transit shocks can sometimes damage instruments internally, although externally they appear to be perfect. Always give the customer full details of any suspected transit damage, particularly when the damage to the instrument is more serious than that reported by him. The customer may wish to claim financial damage from the carrier who shipped the instrument and because of this, the packing material in which the instrument arrived should be retained. It is also important that the carriers should be informed of the damage without delay.

If the customer has not advised that the repair should be proceeded with irrespective of your charge, we strongly advise that the instrument should be examined and an estimate submitted before any work is carried out. (Do not overlook the condition of the leads, prods, clips and batteries when quoting). This procedure and acceptance of the estimate will provide a safeguard against disputes arising over the charge for the work, after the necessary repairs have been completed.

3. CONSIDERATION OF THE CUSTOMER'S REPORT

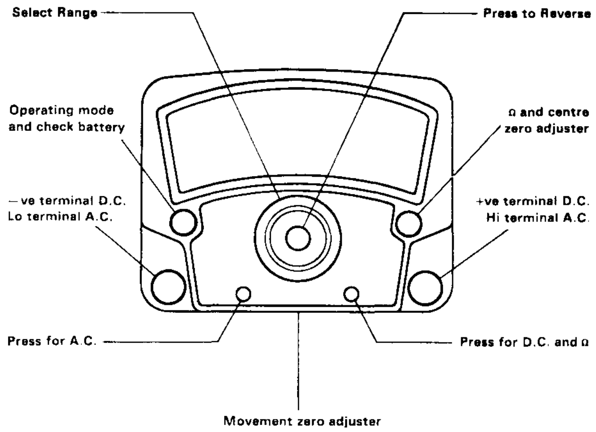
Testmeters requiring no more than the replacement of batteries are often returned for repair and it is therefore advisable to carry out a Battery Check before undertaking any other tests (see Section 4A). If the batteries are found to be exhausted, the instrument should nevertheless be tested throughout before being returned to its owner to ensure that there is no other failure not reported by him.

It may be found that a fault exists which bears no relation to the complaint received. If so, the instrument should be opened (see Section 6) and the full extent of the fault be reported to the customer before proceeding with the repair.

Should the cause of the reported fault not be apparent, it may be one of an intermittent nature, and if it cannot be located the fullest information should be obtained from the customer, as to the symptoms and then concentrate on the likely portions of the circuit. Intermittent faults which can suddenly appear or vanish and vary in intensity from slight to severe can be very misleading during diagnosis and difficult to locate. Intermittent faults can often be traced by changing the instrument operating temperature by $\pm 10^{\circ}$ from ambient temperature.

4. RAPID FUNCTIONAL CHECK

DO NOT OPEN THE INSTRUMENT or adjust the pre-set controls until the necessity to do so has been clearly established. If incorrect operation of the instrument is suspected, the following brief checks should first be made. These checks provide a simple method of determining whether the instrument is functioning normally and they can all be performed without removing the instrument from its case.



(a) With the Range switch set to any position except OFF and the Operating Mode switch set to the positive and negative check battery positions in turn, check the state of the batteries. If the meter indication is below the minimum battery limit marked on the scaleplate, the batteries should be replaced before continuing with any further tests. (See Section 5 for Replacement Instructions.)

(b) With the Range switch set to OFF, the Operating Mode switch set to Check battery positive and the a.c. push-button depressed, check movement mechanical zero. If required mechanical zero can be set using the slotted screw adjuster on the side of the instrument.

(c) Set the Operating Mode switch to the left-hand zero position, depress the d.c. push-button and set the range switch to the .01V position. The meter should read zero within 0.2%.

(d) Check all d.c. voltage and current ranges at f.s.d. to ascertain if they meet the specified accuracy.

(e) With terminals open circuit, set the Range switch to the 1M position and check that full scale can be set using the Ohm and Centre Zero potentiometer on the front panel. The potentiometer should provide an adjustment either side of f.s.d. (of about 10 or 20%). Check zero ohms by shorting the terminals.

(f) Repeat (e) with the Range switch set at positions x100k, x10k, x1k and 100 positions.

(g) Set the Range switch to the .01V position and set Operating Mode switch to the centre zero position. The meter should read approximately half scale. The centre zero potentiometer should provide an adjustment of approximately $\pm$ 10 on the special centre zero scale.

(h) Depress the a.c. push-button and set the Operating Mode switch to the left-hand zero position. The meter should swing to full scale momentarily, then fall back towards zero. Set the Range switch to the 1000V range and zero should be indicated to within $\pm$ 0.2%.

(j) Check all a.c. voltage and current ranges at f.s.d. and note that they meet the specified accuracy.

(k) Remove all test instruments and set the Range switch to the OFF position.

REMOVAL OF ASSEMBLIES

The following notes are given if the necessity to open the instrument has been established. A visual examination of the interior could show where the fault lies, particularly if the fault is due to overloading of the instrument. Unless it is found to be essential the movement should remain undisturbed with the movement cover in place. It must be emphasised that if movement servicing is necessary, the movement must be de-magnetised before any servicing can be carried out. Specialised equipment will be required for this and the movement is such a specialised item that in the event of defects of more than a minor nature, complete replacement is recommended.

5. REPLACEMENT OF BATTERY OR FUSE

Replacement of the battery or fuse is easily effected by releasing the two Dzus fasteners on the backplate. Switch first to the OFF position and then remove the backplate which will reveal the batteries, the fuse and a spare fuse. Polarities are indicated in the battery compartment and it is essential that these are observed when replacing the batteries.

If replacing with Mallory Duracell batteries replace the complete set and ensure that they are inserted in the correct polarity. Under certain atmospheric conditions a 'white frosting' may appear on these battery terminals. This is quite harmless, but should be removed with a soft cloth to ensure perfect contact. (This refers only to Mallory Duracell batteries.)

The fuse rating is 3A and recommended replacement batteries are as follows:

Four Mallory Cells type ZM 9 as supplied with the instrument. These will give approximately nine months continuous operation.

Alternatives:

Four HP7, V12 or D14 (AA) batteries. With these alternatives the battery life will be reduced to approximately three months continuous operation.

6. REMOVAL OF THE PANEL FROM THE CASE (Plate 1)

If it is necessary to open the instrument (see notes which follow regarding fault finding) it should be placed on the bench front panel downwards and the Instruction Plate removed as above together with the four additional screws (items 16 and 23) in the base of the case. A heated screwdriver facilitates removal of the wax seal. The case can now be lifted off to lie alongside the panel, taking care not to break the battery connections. To completely remove the case the battery connections should be disconnected. Take particular note of these connections in order that they can be correctly connected after repair.

When replacing the four screws in the base of the case ensure that these are not over-tightened as this could cause damage to the case.

7. REMOVAL OF THE PRINTED CIRCUIT RANGE BOARD (Plate 1)

This board is immediately visible after removal of the case. Remove the two screws (item 15) which will enable the moulded bar (item 14) to be removed. Take particular care not to lose the nylon washers. Unscrew the short hexagon pillar (item 10) and unsolder the two movement connecting wires from the printed circuit board. These are the two flexible leads soldered to the line of the connectors at the bottom edge of the board. The board can now be lifted off, but to completely free the board, all connections to the board will have to be unsoldered. Note position of these connections.

Particular care must be taken when lifting off the board to gently ease the board off the switch spindle. It has been found that exerting slight pressure with the thumbs on the black switch arm enables the board to be lifted off without difficulty.

Any washer underneath the hexagon pillar (item 10) should be replaced when the board is re-assembled. If there is no washer it is not required. Note: these are packing washers and it is essential that they are replaced in their original position.

Individual components on this board can be readily replaced after identification. If however, it is necessary to remove the slide switch, some form of solder removing iron will be required. When servicing printed circuit boards great care is required to ensure that the minimum of solder is used as excessive solder could cause short circuits. After any repair work on the printed circuit boards all residue flux and dirt must be cleaned off.

8. REMOVAL OF THE AMPLIFIER BOARD (Plate 1)

After removal of the case and the Range Board, remove the screening plate. To do this, remove the bakelite washer from the switch spindle and the three round headed screws. Take particular care of these screws as it is essential that round headed screws are used when the screening is replaced. Care should be taken not to exert too much pressure on the black washer on the switch spindle as this will distort the switch contacts.

The covers must be removed from the Ohms and Centre Zero Adjuster and the Operating Mode control mounted on the front panel (items 7 and 8). Note the position of the battery check control in order that when replacing, the arrow on this switch is replaced in the correct position. Remove the grub screws from the metal inserts using Allan Key No.K11 and remove the inserts from the spindles. After unsoldering all connections to this board, it can be removed. The circuitry can easily be traced as all components on the board are identified by their circuit references. The notes regarding the servicing of printed circuit boards in Section 7 should be observed.

9. REMOVAL OF THE MOVEMENT FROM THE PANEL (Plate 1)

Unless it is absolutely essential the movement should not be disturbed and the movement cover should remain in place. If it is really necessary to remove the movement, the following instructions should be carefully followed.

Having removed the case and the printed circuit boards remove the movement cover and unsolder the connections to the movement assembly. The two screws and nylon washers (items 20 and 21) should be removed together with the two scaleplate retaining screws (item 28). The complete movement assembly may now be lifted from the panel. Take particular care of the nylon washers and when they are replaced ensure that they are securely screwed down.

The movement is such a specialised item that in the event of defects of more than a minor nature, it is recommended that a complete replacement should be used. If repairs to the movement are necessary it must be de-magnetised before any repairs can be carried out and after repair the sensitivity will have to be adjusted as in Section 12. The scaleplate may need replacement and re-calibration to regain the original accuracy. Re-balancing will be necessary and the magnet will have to be re-magnetised when repairs are complete.

The associated movement board is readily visible after removal of the amplifier board. Remove the screws securing this to release the board.

To replace the movement the procedure outlined above should be reversed. Care must be taken to ensure that the zero adjuster screw engages with the slot.

FAULT FINDING AND SERVICING INFORMATION

10. FAULT FINDING TABLE

The following table is given to assist in the rapid location of a fault. Comprehensive servicing details follow. See Section 11 (a) to (r) inclusive.

	SYMPTONS	PROBABLE FAULT
(a)	No reading on any range or intermittent reading only.	Leads open circuit or intermittent, faulty fuse or switch fault. Moving coil open or short circuit.
(b)	No reading on an isolated current, voltage or resistance range.	A faulty connection between switch contact or ranging resistors.
(c)	No d.c. voltage or current reading.	Faulty d.c. amplifier.
(d)	One or more d.c. current or voltage ranges inoperative.	One or more ranging resistors faulty.
(e)	Incorrect or no reading on a.c. but correct on d.c.	Suspect a faulty a.c. amplifier or ac/dc switch.
(f)	Ohms range inoperative, intermittent or incorrect.	Possible fault in the constant current circuitry.
(g)	Inability to attain ohms full scale setting or drifts shortly after being set.	Possible battery failure or fault in constant current circuit.
(h)	Unable to adjust to centre zero.	Battery fault or constant current circuit faulty.
(j)	Low readings on all current and voltage ranges.	Battery failure or amplifiers faulty.
(k)	Pointer sticks at one particular point.	Amplifier faulty or dust, hair or other foreign body fouling the movement.
(m)	Pointer stuck firmly.	Pivot out of jewel.
(n)	Slight uniform pointer stick over the whole scale.	Tight in jewels, blunted pivots, dirt in jewels or possible damaged jewels.
(p)	Incorrect readings on low a.c. ranges, pointer swings to f.s.d. on switching on.	Prods not making good contact.
(q)	Instability of readings.	Metallic coating inside case not satisfactorily earthed.
(r)	Pointer moves from position of rest by more than 1% of the maximum scale value when the instrument is held in any position within 45° from normal.	Movement out of balance.

11. SERVICING INFORMATION

To enable the most suitable method of repair to be selected the information obtained from the Table in (10) should be carefully considered together with any information obtained from Section 4 and the servicing information which follows this section.

It must be emphasised that due to the constant voltage characteristic of the batteries supplied with the instrument, the voltage falls rapidly at the end of life. This fact should be borne in mind whilst attempting to trace faults in the circuit and the batteries should be checked at suitable intervals.

The information in this section is cross-referenced to the alphabetical sequence in the fault-finding table i.e. if the symptom and possible fault appear at (f) in the fault-finding table, the relevant servicing information will be found at (f) in this section. It must be emphasised that before servicing can be carried out on the movement it must be de-magnetised.

(a) No reading on any range or intermittent reading only

The leads should be checked for open circuit and the fuse examined. If neither are faulty check for open or short circuit meter movement.

(b) No reading on an isolated Current, Voltage or Resistance range

If only one range is found to be at fault, the ranging resistors associated with that particular range should be checked. The connections between the relevant switch contact and the shunt or multiplier concerned should be checked with an ohmmeter to see if there is a dry joint and correction made as necessary.

(c) No d.c. voltage or current readings (or erratic readings)

The fault will almost certainly be in the d.c. amplifier and this should be tested in accordance with the test specification in Section 17.

(d) One or more d.c. voltage or current ranges inoperative

One or more shunt or multiplier resistors may be faulty.

(e) Incorrect, or no reading on a.c. but is correct on d.c.

This fault will almost certainly be caused by a defective a.c. amplifier and this should be tested in accordance with the test specification. (See Section 18). Alternatively this fault may be due to a faulty ac/dc switch and this should also be checked.

(f) Ohms range inoperative, intermittent or incorrect

If the ohms range is inoperative or incorrect, VT11 and associated circuitry should be checked. If the ohms ranges have been overloaded R62, R63 or associated circuitry could be damaged.

(g) Inability to attain ohms full scale setting or drifts shortly after being set

Check VT11 and associated circuitry.

(h) Unable to adjust to centre zero

The batteries should be checked but if these are satisfactory VT11 and associated circuitry should be checked.

(j) Low readings on all current and voltage ranges

If batteries are satisfactory check both a.c. and d.c. amplifiers as outlined in the test specification. See Sections 17 and 18.

(k) Pointer stick at one particular point

This sympton often indicates that dust, a small piece of iron or some other foreign body is possibly fouling the moving coil former. Specks of dust or even a hair, if present, can be removed with a fine needle.

A minute hair on the scaleplate or on the window glass could cause sticking and this may only show up in a bright light. In all such cases sticking might also be dependent upon a slight tilt of the instrument associated with the small but essential pivot play. Should the fault not be cleared check the amplifiers as outlined in the appropriate test specification.

Unless it is essential the movement should not be dismantled.

(m) Pointer stuck firmly

It can occasionally happen that severe mechanical shock can cause a pivot to leave its jewels and become lodged in the end of a jewel screw, which would result in the pointer becoming firmly stuck. Do not try to push the pivot back as damage will occur. A slight re-adjustment of both top and bottom jewel screws may cure the fault, but if it still persists, the moving coil assembly will have to be replaced.

(n) Slight uniform pointer stick over the whole scale

This may be due to a slight tightening of the moving coil between the spring mounted jewels. With the movement horizontal a minute clearance between the top jewel and pivot should permit of a slight sideways rock. The jewel assembly will show a sideways rock if adjustment is too tight, due to the jewel being raised from its seating. The movement in such a case, would show a peculiar change of swing just before coming to rest and furthermore, the instrument held on its side might also show complete instability of zero reading. Slightly easing the top jewel screw will indicate if this is the cause of friction and effect a cure. If this type of stick cannot be cured by jewel screw adjustment it will be necessary to dismantle the movement for repair or replace it completely.

(p) Incorrect readings on low a.c. ranges, pointer swings to f.s.d. on switching on

This may be due to the fact that the prods are not making good contact and this should be checked.

(q) Instability of readings

The metallic coating inside the case is earthed through the battery. If readings appear to be unstable check that this earthing lead is satisfactory. This is the black lead connected directly between Range board and negative terminal.

(r) Movement out of balance

The moving coil is balanced when the instrument leaves the factory but very severe overload, mechanical shock or pivot damage, may cause it to become unbalanced. The balance limit permitted in BS 89 allows a pointer change of $\pm$ 1% of maximum scale values when the instrument is held in any position within 45° from horizontal.

If the movement needs re-balancing, it should be mounted in a draught-proof box and tested in four positions with the axis horizontal for tests 2, 3 and 4:

(1) Set the pointer to zero with the instrument in a horizontal position.

(2) Check zero position with pointer horizontal and pointing left.

(3) Check zero position with pointer horizontal and pointing right.

(4) Check zero position with the pointer vertical upwards.

The balancing box should be tapped lightly during balancing operations to ensure that pivot friction does not interfere with the balance effect. If a satisfactory balance cannot be achieved, the pivots will almost certainly be defective.

If a new coil is fitted major balancing is called for. The balancing of an instrument calls for a high degree of skill and once again we advise that if the trouble is difficult to cure, the whole movement assembly should be replaced.

12. DISMANTLING THE MOVEMENT (Plate 2)

If adequate facilities and skill are available for major movement repair, certain spares are available. The moving coil complete with pointer, hairsprings and pivots can be supplied, but the replacement of such a unit in the movement, requires care and will necessitate adjustment of the sensitivity to 36-37μA, recalibration and also the possible replacement of the scaleplate in order to regain the original accuracy. The fitting of a new moving coil will also necessitate the re-balancing of the movement whilst the magnet will have to be re-magnetised and aged before the correct sensitivity can be met.

If a movement is changed always ensure that any serial number marked on the scaleplate is transferred to the scaleplate of the replacement movement. The defective movement can be returned and allowance will be made for any useful component parts.

The following notes are given to assist in the dismantling and repair of the movement:

Having removed the movement from the panel assembly (see Section 9) remove the scaleplate from the movement. Before any further work is carried out, the magnet must be de-magnetised. This can best be done with the use of the Avo Magnetising Unit which is available from Avo Limited.

The movement should then be dismantled in the following order:

First remove the reversing switch bar (item 11). To do this remove the circlip (item 14), hinge the bar free from the reversing switch spindle and withdraw sideways from the fulcrum pin (item 3/1).

Unsolder the outer ends of the two hairsprings and disconnect the connections from the top and bottom zero adjuster.

NOTE: When dismantling it is essential that a note is made of the magnet axis identification mark as it is important that the magnet be re-assembled with the axis in the original position.

With item 4 uppermost and item 5 in the centre scale position, place the movement on assembly jig Avo Part No. AF 5075. Remove the two screws (items 8 and 9). Press items 1 and 2 firmly downwards against the assembly jig and remove item 4 by gently levering upwards.

NOTE: Items 1, 2, 3 and 4 are assembled with LOCTITE retaining compound (Green) and care must be exercised when dismantling these items.

Press item 2 firmly down against the assembly jig and remove item 1 by pulling upwards. Press item 3 firmly down against the assembly jig and remove items 2 and 5 from the jig by pulling upwards. Separate items 2 and 5. Remove item 3 from the jig.

Remove all traces of retaining compound from items 1, 2, 3 and 4.

Unlock and slacken back the jewel screws on items 3 and 4 so that the face of the screw is flush with the inside face of the bridge piece.

Parts may now be examined and cleaned as follows:

Sticking can be due to dust or rustlike deposition which sometimes forms on the tip of the pivot and in the jewel and it may be worthwhile seeing if its removal cures the stick rather than replace the movement or parts. If a microscope is available (having a magnification of X100 or better) place the jewel screw on the table with the jewel uppermost, illuminate well and examine. It is very difficult to diagnose small mechanical damage optically, but the presence of foreign matter such as red deposit arising from wear is readily apparent.

The jewels can be cleaned using a piece of pegwood cut with a very sharp knife or razor blade to a diameter which will enter the end of the jewel screw. The tip must be brought to a very fine point and there must be no loose fibres left. Soak the jewel in Trichlorethylene and holding the jewel downwards, wipe the interior. Brush the jewel, still inverted, with a fine dry, clean pencil brush and then examine the jewel under the microscope in a good light to ensure that all rustlike deposit or other foreign matter has been removed. If cracks are detected the jewel must be replaced.

Sticking could also be caused by a damaged pivot. The pivot should be examined under a microscope and if it should require cleaning this can be done by rotating the end of a piece of impregnated pegwood on the pivot tip and then pressing it into a piece of cork or pith. Re-examine the pivot to see if it can be used or if it should be replaced. An undamaged tip should have a spherical radius of .0004 in. If any departure from the spherical shape is evident or if its radius has become excessive a replacement moving coil assembly will be required. If a jewel screw is rested on the tip of the pivot, the clearance between the end of the screw and the pivot holder should be in the order of .012 in. This can determine the maximum jewel retraction under the influence of impact.

A damaged jewel, (which is a most infrequent occurrence) must always be replaced by a similar one supplied in its spring mounting.

Before re-assembling, items 8 and 9 should be renewed.

To re-assemble the movement, reverse the dismantling procedure, but do not replace the reversing switch bar (item 11). Ensure that item 2 is replaced with the identification mark in the original position. Tighten item 8 with a torque screwdriver to 4 in. lb.

Remove the assembly from the jig and inject LOCTITE retaining compound (Green) into the mating surfaces of items 1, 2, 3 and 4, taking care that the liquid does not contaminate item 5.

Solder the outer tails of the hairsprings to the zero adjuster tags and reconnect the circuit wires to the top and bottom zero adjusters. Replace the scale-plate.

IMPORTANT NOTE. Each movement is individually calibrated and is matched to a scale-plate of a particular characteristic. If the movement is repaired and is not re-calibrated it must be recognised that the accuracy will almost certainly be impaired.

Balance the movement to within $\pm$ 1% of f.s.d. Gently rotate the spindle of Potentiometer RV3 (22kΩ) in a counter-clockwise direction until the end-stop position is reached.

Re-charge the magnet circuit to give a full scale current sensitivity of approximately 33μA.

Carefully discharge the magnet circuit until, with the pointer resting at full scale, the current sensitivity is between 37.7 and 38.1μA.

NOTE: During the discharge procedure make frequent checks to ensure that the pointer rests on the scale zero when no current flows.

Stove the complete assembly for 10 hours at 70°C and then allow to stabilise for 10 to 14 days at 15 to 25°C. At the completion of this period check the side and end clearance of the movement and adjust if necessary.

Check the movement for freedom from stick or foreign matter in both horizontal and vertical positions.

Set the top zero adjuster in the central position and set the bottom zero adjuster to bring the knife edge pointer exactly over the scale zero.

Re-balance the movement to within $\pm$ 0.5% of f.s.d. Pass 37.5μA through the movement and adjust the 22kΩ potentiometer to bring the pointer to full scale $\pm$ 0.2% of f.s.d. Check all cardinal points on the scale for correct current sensitivity.

The reversing switch bar may now be replaced and the movement re-assembled on the panel assembly using the reverse procedure to that described in Section 9.

13. FRONT PANEL REPLACEMENT (Plate 3)

Having removed the Range and Amplifier printed circuit board assemblies (see Sections 7 and 8) and the Movement assembly (Section 9) the remainder of the front panel components must be transferred to the replacement front panel. This should be carried out as follows:

Remove the switch knob circlip (item 10). This will require a pair of special circlip pliers. Care should be taken not to lose the click balls or springs located between knob and panel. Remove the slide switch bar clips (item 24) again these can be cut as new ones are provided. The whole of the changeover switch mechanism can now be lifted out of the panel.

Remove the zero adjuster retaining clip (item 14) and the zero adjuster knob from the panel. Remove the two terminals by unscrewing the nuts (item 19) using a 5/16 in. BSF spanner.

These items may now all be re-assembled on the replacement front panel assembly using the new spring retainers where provided. See Plate 3 for gear wheel assembly instructions.

14. REPLACEMENT OF SLIDE SWITCH ASSEMBLY

This may be removed from the printed circuit board if care is taken. Using a solder removing iron, unsolder each connection in turn, making sure that sufficient solder is removed to release the connections from the board. When replacing, carefully remove solder from the holes on the board to which the connections must be soldered. This can best be carried out using a vacuum de-soldering tool, but if this is not available the solder should be melted and the holes cleaned by a sharp blast of air.

Take the new slide switch and solder all connections to the appropriate points.

ELECTRICAL TESTING

15. TRANSISTOR SELECTION PROCEDURE

F.E.T. Selection: Should it be necessary to replace either VT1 or VT12 one having the correct characteristics will be necessary and selection will be required. A suitable test circuit is shown in Fig. 1 which will enable this selection procedure to be carried out.

The selection procedure is as follows:

(a) With the Supply switch at OFF turn the potentiometer knob on the test gear fully clockwise.

(b) Connect the F.E.T. to be tested and switch ON.

(c) Rotate the potentiometer anti-clockwise until a reasonable reading is obtained, then rotate the potentiometer clockwise until the meter just reads $1\mu A$.

(d) The position of the potentiometer will now indicate whether the F.E.T. is suitable for use for the d.c. amplifier, the a.c. amplifier or whether it is to be rejected. (As indicated on the drawing the potentiometer must first be calibrated and the divisions marked appropriately.)

NOTE: An F.E.T. selected for the d.c. amplifier may be used in the a.c. amplifier, but an F.E.T. selected for the a.c. amplifier cannot be used in the d.c. amplifier.

Selection of BC.183's for a.c. amplifier: Transistors for use in positions VT14 and VT15 must be gain-selected in order to eliminate offset zero readings on a.c. functions. Similarly transistors for use in VT5 and VT6 positions require gain-selection to ensure that the d.c. amplifier zero can be set within the range of RV4.

Using a Transistor Test Set Type TT.166, check the gain of the transistors type BC.183 for h_{FE} at an IC of $10\mu A$. Select those with an h_{FE} between 200 and 300, for use in VT5, VT6, VT14 and VT15 positions. Yield should be about 40%.

16. GENERAL FUNCTIONAL CHECK

To ensure that the instrument is now functioning the brief checks outlined in Section 4 should be carried out before detailed checks on the a.c. and d.c. amplifiers.

17. D.C. CALIBRATION TESTS AND ADJUSTMENTS

(a) With the Range switch set to the OFF position, set the Operating Mode switch to Battery +ve and depress the a.c. push-button.

(b) Check mechanical zero and adjust if necessary.

(c) Depress the d.c. push-button, set the Range switch to .01V and the Operating Mode switch to left-hand zero. Check zero. This should be within 0.2% and can be re-set with RV4 if necessary.

(d) Check on the 100 and 1000V ranges that zero is also within ± 0.2%.

(e) Set the Range switch to the .03V range. Connect the d.c. Calibrator (whose output is monitored with the Avo Digital System) to the input terminals of the instrument and apply 30mV. Using RV1 set pointer to the 30 mark on the 0-30 scale.

(f) Select all other d.c. voltage ranges in sequence and check that the meter reads within ± 1% of selected full scale reading.

(g) Set the Range switch to the .01mA range. Apply .01mA d.c. using the test console. The meter reading should be within ± 1%. Repeat this check on all other d.c. current ranges. The meter reading should be ± 1% of selected full scale reading in all cases.

(h) If 100mA ranges upwards are incorrect, apply 100mA from test console and adjust yellow wire tap on 100mA shunt until meter pointer reads 100. Solder the joint. Repeat on the 1000 and 3000mA ranges.
NOTE: Time must be allowed after soldering for shunt to return to ambient temperature before re-checking.

(j) Depress the a.c. push-button and check all a.c. current ranges on a.c. to within ± 1%.

(k) Depress the d.c. push-button and set the Range switch to 1M. With console switch to ohms (Ω) set f.s.d. with right-hand control marked (Ω). Check scale with the following resistor values set on console 10MΩ. 5MΩ, 1MΩ and 200kΩ. Readings should be within ± 1 division referring to the top scale.

(m) Check half scale on all other ohms ranges.

(n) Switch OFF and remove all test gear.

18. A.C. CALIBRATION TESTS AND ADJUSTMENTS

(a) With the Operating Mode switch in the left-hand zero position depress the a.c. push-button and set the Range switch to 30mV.

(b) Connect the a.c. calibrator to the input terminals, apply 30mV and sweep from 10Hz to 50Hz. The reading should be within ± 2% of f.s.d. between 10Hz to 20Hz and ± 1% from 20Hz to 50Hz.

(c) Sweep from 20kHz to 100kHz. Between 20kHz to 25kHz the readings should be within ± 1% of f.s.d. From 25kHz to 50kHz the readings should be within ± 2.25% of f.s.d. and from 50kHz to 100kHz the readings should be within ± 5% of f.s.d. Ensure also that troughs and peaks are within the limits specified.

(d) Check all voltage ranges at 50kHz at f.s.d. Readings should be within ± 1% of f.s.d.

(e) Set the Range switch to 100V and apply 100V at 20kHz. Adjust C25 to set pointer 0.8% low of f.s.d. Sweep from 20kHz to 100kHz. Limits are as detailed in (c). C25 may be re-adjusted to achieve these limits.

(f) Set the instrument to 1V range. Apply 1V from the calibrator. Adjust C28 to set the pointer 0.8% high at 20kHz. Sweep from 20kHz to 100kHz. Limits are as detailed in (c). C28 may be re-adjusted to achieve these limits.

(g) Set the instrument to the 30V range and apply 30V from the calibrator. Sweep from 20kHz to 100kHz. Limits to be as detailed in (c). C25 and C28 may require adjustment to achieve these limits. If these capacitors have to be re-adjusted repeat (e) and (f).

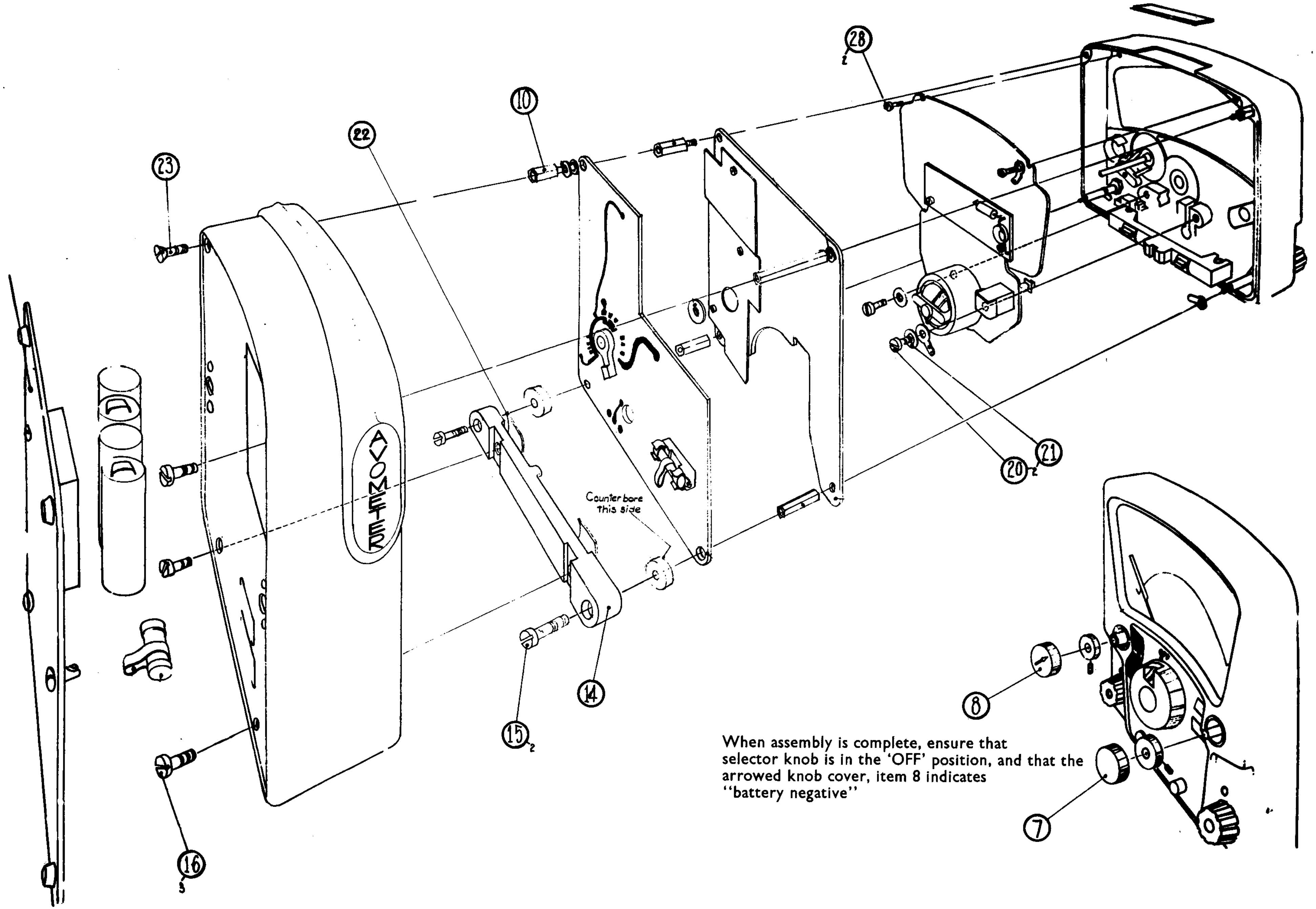
(h) Check the 300V and 1000V ranges at 10kHz using the high voltage amplifier. The meter should read within ± 2.5% of f.s.d.

(j) Switch OFF and remove all test instruments.

19. FINAL PROCEDURE.

When all the faults have been satisfactorily cleared and the meter meets the accuracy requirements ensure that the case and window glass are clean and bright. Air blasting will ensure that the panel is clean. Attention to this final detail will give the correct impression that the meter has received careful and painstaking attention.

Before despatch the Range switch should be set to the OFF position and the Operating Mode switch to check battery -ve.



When assembly is complete, ensure that selector knob is in the 'OFF' position, and that the arrowed knob cover, item 8 indicates "battery negative"

PLATE 1 INSTRUMENT ASSEMBLY

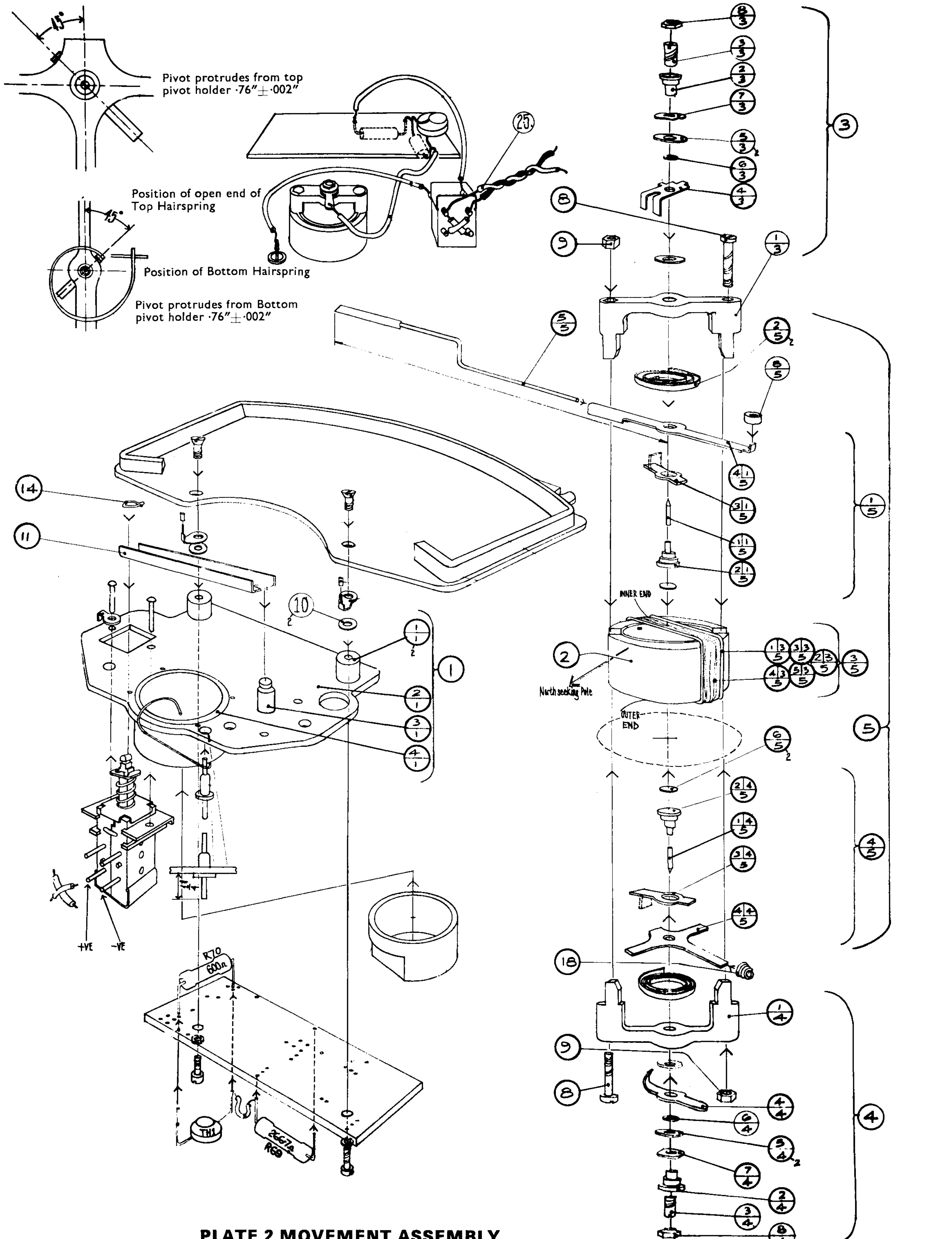


PLATE 2 MOVEMENT ASSEMBLY

IMPORTANT NOTE:
SETTING OF GEAR WHEEL (ITEM 12) IN FRONT PANEL. SET KNOB (ITEM $\frac{1}{6}$) ON FRONT PANEL TO 100 Ω RANGE THEN ALIGN MARK ON GEAR WHEEL & FRONT PANEL IF TWO MARKS DON'T ALIGN MARK ON GEAR TO BE OFF SET TOWARDS GLASS.

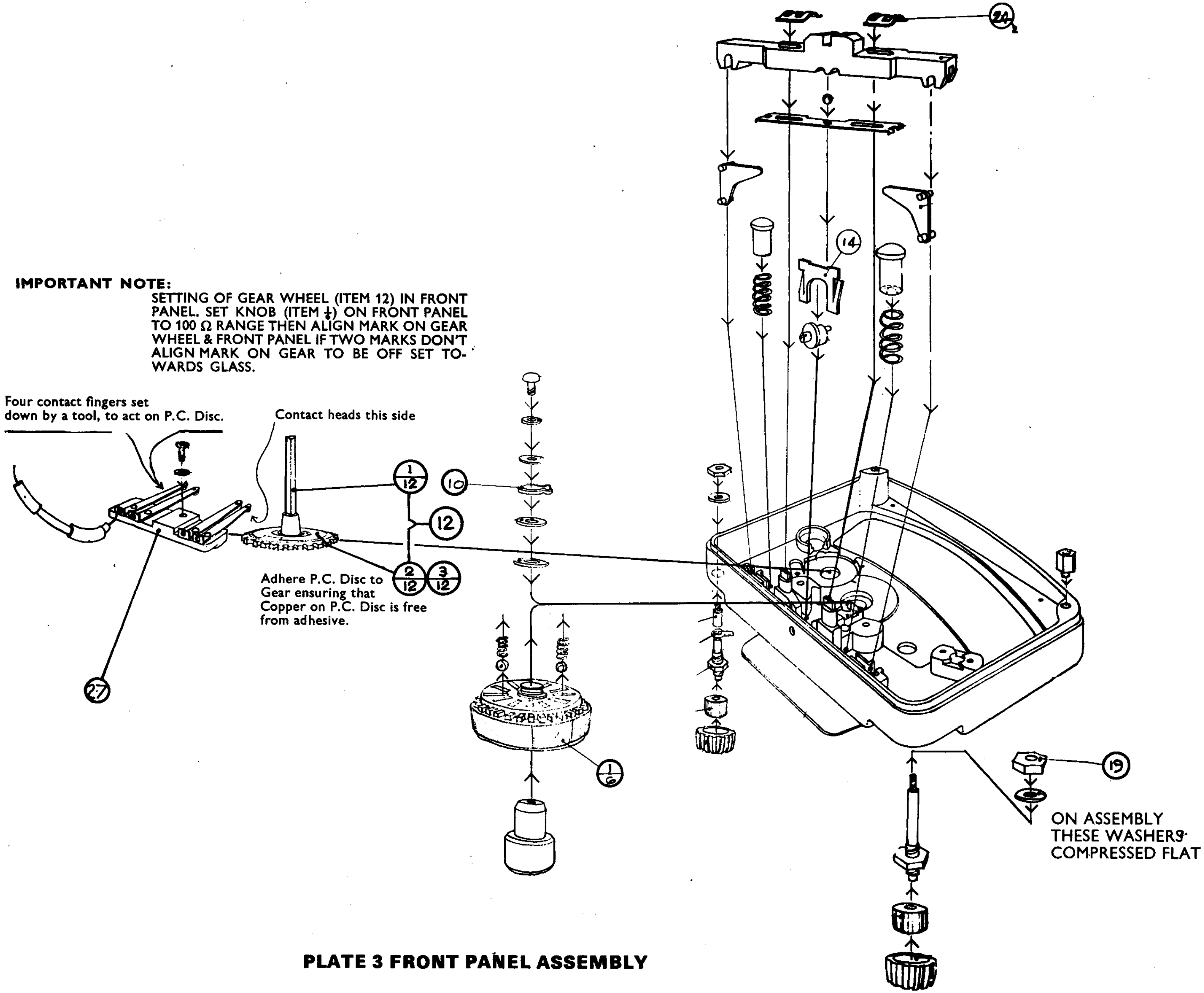


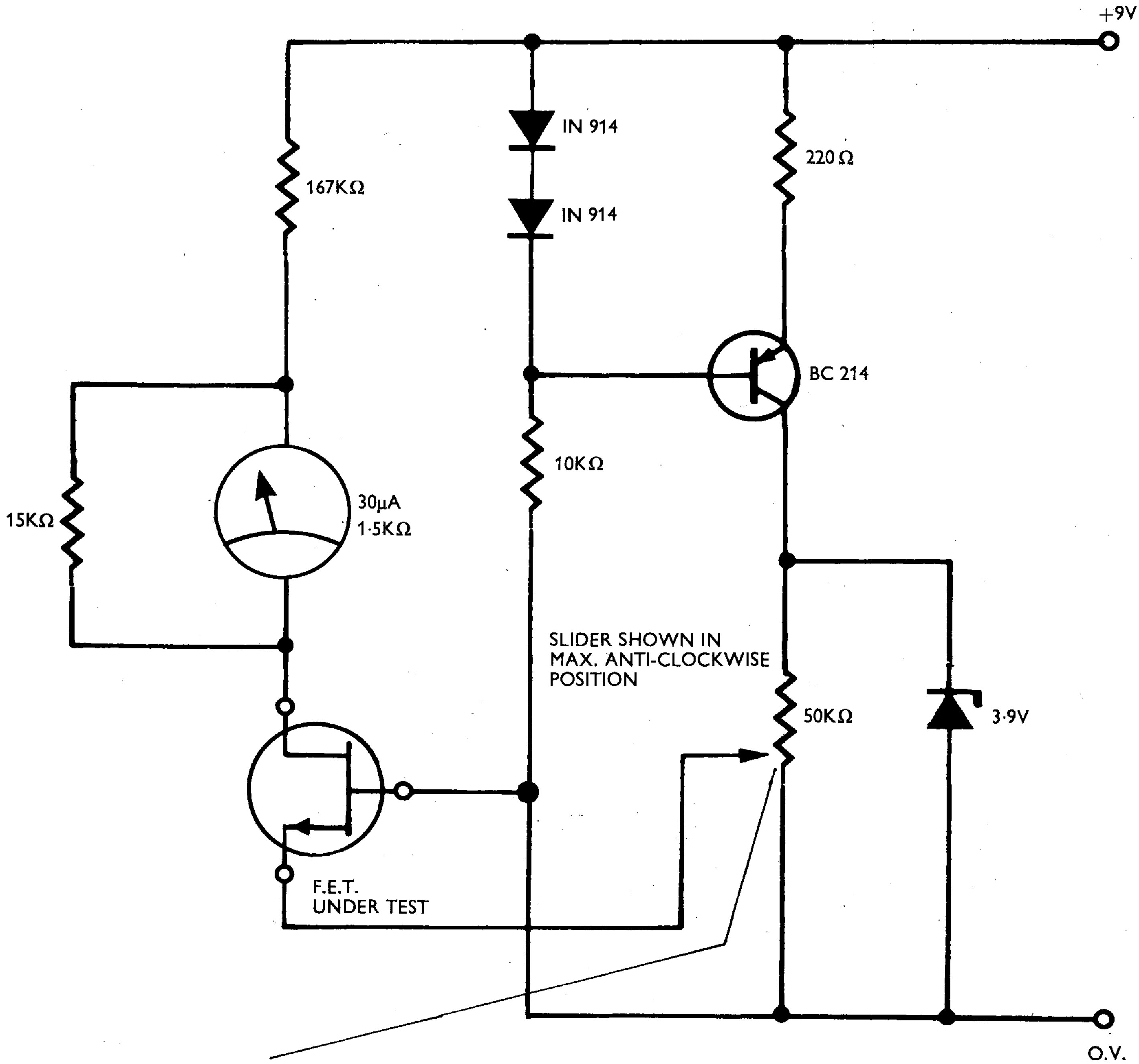
PLATE 3 FRONT PANEL ASSEMBLY

COMPONENTS LIST

R1	1MΩ ± 2% MR5
R2	1MΩ ± 2% MR5
R3	120kΩ ± 5% CR25
R4	240kΩ ± 5% UMP ¼ WATT.
R5	39kΩ ± 5% CR25
R6	18kΩ ± 5% CR25
R7	56kΩ ± 5% CR25
R8	11·1kΩ ± 0·3% 4033Z
R9	43kΩ ± 0·3% 4033Z
R10	100kΩ ± 0·3% 4013C
R11-12	100k ± 5% CR25
R13	270kΩ ± 5% CR25
R14	150kΩ ± 5% CR25
R15	180kΩ ± 5% CR25
R16	27kΩ ± 5% CR25
R17	6·8kΩ ± 2% MR30
R18	47kΩ ± 5% CR25
R19	470kΩ ± 5% CR25
R20	2kΩ ± 2% MR5
R21	560kΩ ± 5% CR25
R22	47kΩ ± 5% CR25
R23	100kΩ ± 5% CR25
R24	1·1MΩ ± 1% 4013D
R25	10kΩ ± 2% MR30
R26	31·6kΩ ± 1% 4033Z
R27	10MΩ ± 10% CR25
R28	100kΩ ± 2% MR30
R29	10MΩ ± 10% CR25
R30	1MΩ ± 2% MR5
R31	18kΩ ± 5% CR25
R32	10kΩ ± 5% CR25
R33	10·21kΩ ± 0·3% 4033Z
R34	3·28kΩ ± 0·3% 4033Z
R35	1·033kΩ ± 0·3% 4033Z
R36	475Ω ± 0·3% 4013D
R37	470kΩ ± 5% CR25
R38	47kΩ ± 5% CR25
R39	56kΩ ± 5% CR25
R40	15kΩ ± 5% CR25
R41-42	240kΩ ± 5% UMP ¼ WATT.
R43	5·6kΩ ± 5% CR25
R44	1·5kΩ ± 5% CR25
R45	6·8kΩ ± 2% MR30
R46	91Ω ± 2% MR30
R47	6·8kΩ ± 2% MR30
R48	34·19MΩ ± 0·5% 4037Z
R49	21·62MΩ ± 0·5% 4037Z
R50	6·838MΩ ± 0·5% 4036Z

R51	2·162MΩ ± 0·5% 4036Z
R52	683·8kΩ ± 0·3% 4016D
R53	216·2kΩ ± 0·3% 4034Z
R54	68·38kΩ ± 0·3% 4034Z
R55	21·62kΩ ± 0·3% 4034Z
R56	10kΩ ± 0·3% 4034Z
R57	10kΩ ± 1% 4034Z
R58	1·11kΩ ± 1% 4034Z
R59	10kΩ ± 1% 4034Z
R60	101Ω ± 1% 4034Z
R61	31·62 kΩ ± 0·3% 4034Z
R62	10kΩ ± 2% MR30
R63	120kΩ ± 2% MR30
R64	1MΩ ± 0·3% 4037Z
R65	100Ω ± 0·3% 4034Z
R66	10·1kΩ ± 0·3% 4034Z
R67	62kΩ ± 2% MR30
R68	13k/27kΩ ± 2% MR30 (Select on test)
R69	266·7Ω ± 0·5% 4034Z
R70	600Ω ± 1% 4034Z
R71	13kΩ ± 2% MR30
R72	3·52kΩ ± 0·3% 4034Z
R73	319·4Ω ± 0·3% 4034Z
R74	31·65Ω ± 0·3% 4034Z
R75	3·16Ω ± 0·3% 4034Z
R76	0·316Ω Pt.No. A3216–812
R77	0·0316Ω Pt.No. A3216–752
R78	0·01Ω Pt.No. A3216–751
R79	5·6kΩ ± 5% CR25
R80	8·2kΩ CR25
R81	34·19MΩ ± 0 5% 4037Z
R82	62kΩ ± 2% MR30
RV1-2	10kΩ ± 20%
RV3	22kΩ ± 20%
RV4	2·5kΩ ± 20%
C1	0·1μF ± 20% 100V
C2	64μF + 50 – 10% 4V
C3	0·1μF ± 20% 100V
C4	1000pF ± 5% 350V
C5	1μF ± 20% 100V
C6-7	2200pF ± 20% 160V
C8-9	4700pF ± 20% 100V CDV13
C10	0·1μF ± 20% 100V
C11	1μF ± 20% 100V
C12	5μF+ 50 – 20% 10V Solid tantalum

C13	100pF ± 5% 200V
C14	0·1μF ± 20% 100V
C15	47pF ± 5% 350V
C16	10pF ± 5% 350V
C17	1μF ± 20% 100V
C18	0·1μF ± 20% 100V
C19	5μF + 50 – 20% 10V Solid tantalum
C21	100pF ± 5% 200V
C22-24	0·1μF ± 20% 100V
C25	1–8pF J.F.D. Stangard
C26	0·068μF ± 5% 100V
C27	470pF ± 2% 350V
C28	60–180pF
C29-30	0·1μF ± 20% 100V
C31	10pF ± 5% 350V
C32	0·047μF 250V
C33	0·47μF ± 20% 100V
C34	10μF 10V Solid tantalum
D1–6	IN914
D7	Not used
D8–9	IN914
D10–11	BYX 36–150
D12–13	IN914
D14	IN914
D15	OA47
D16–17	IN914
M1	Meter Movement 36–37μA f.s.d
VT1	MPF 103
VT2–10	BC 183
VT11	BC 214
VT12	MPF 103
VT13	BC214
VT14-15	BC183
VT16	BC 214
VT17	BC 183
TH1	Thermistor VA 1039



Vp > 2·7 Volts — Reject

Vp 1·9 to 2·7 Volts — Use in A.C. Amplifier

Vp < 1·9 Volts — Use in D.C. Amplifier

"Pinch-off" current is defined as being 1μA.

FIG. 1 F.E.T. TEST SET

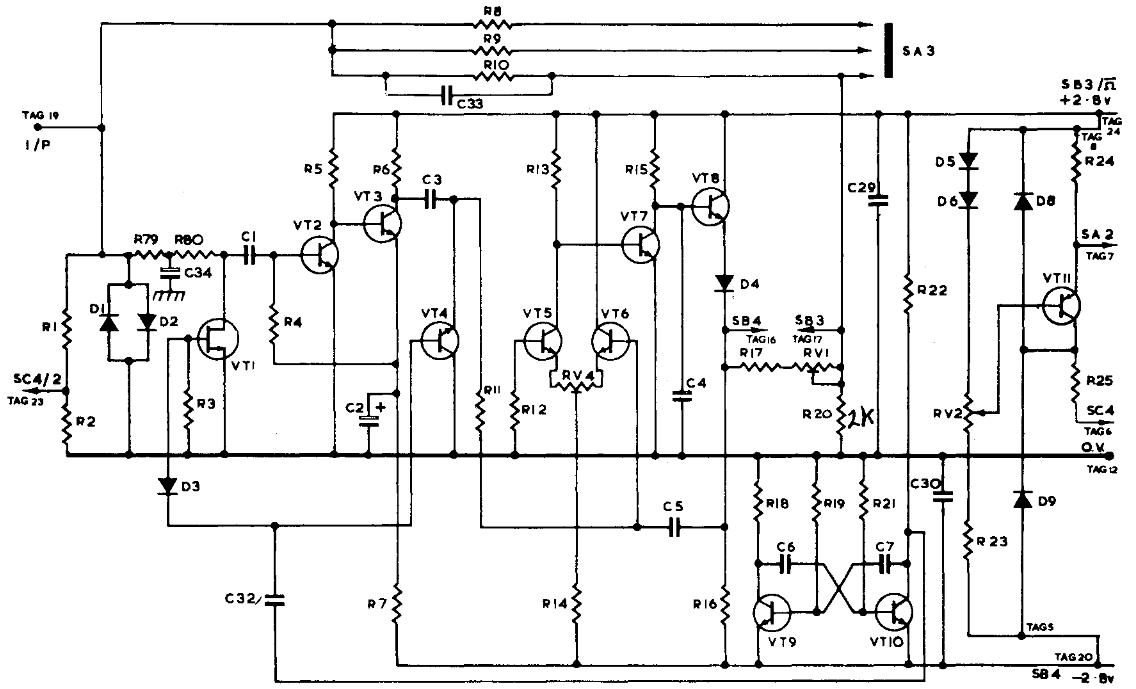


FIG. 2 D.C. AMPLIFIER CIRCUIT DIAGRAM

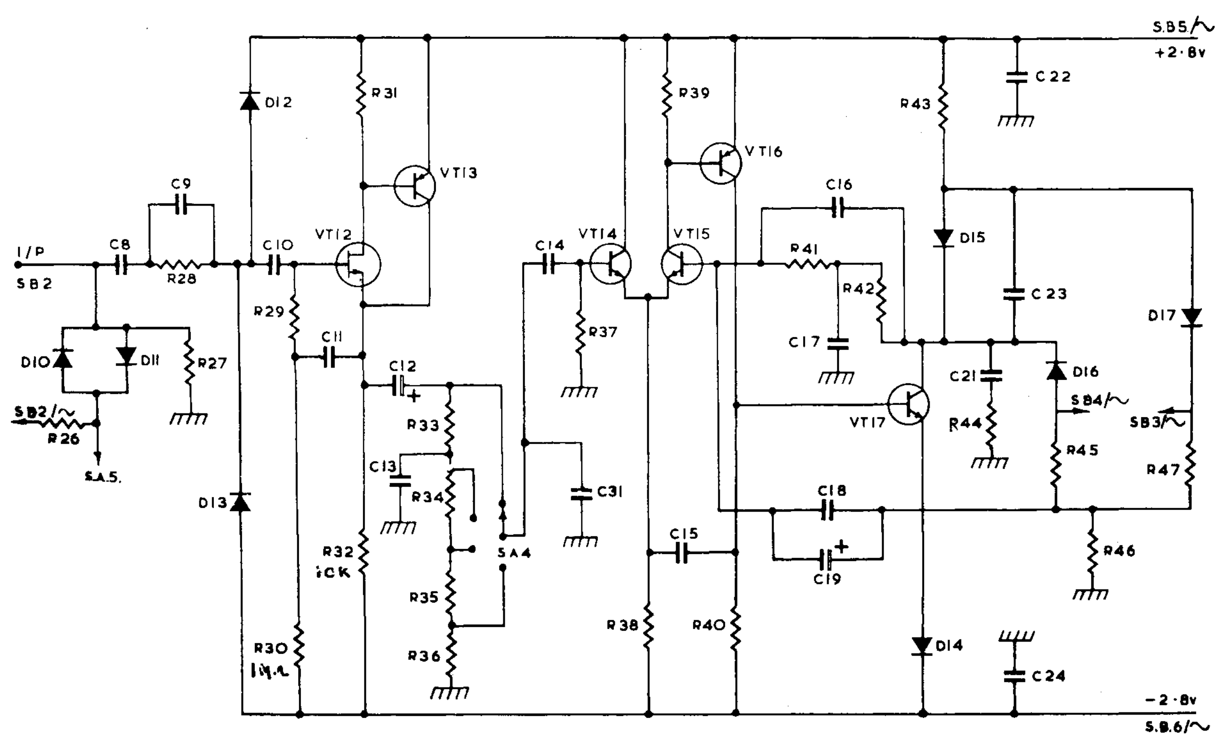
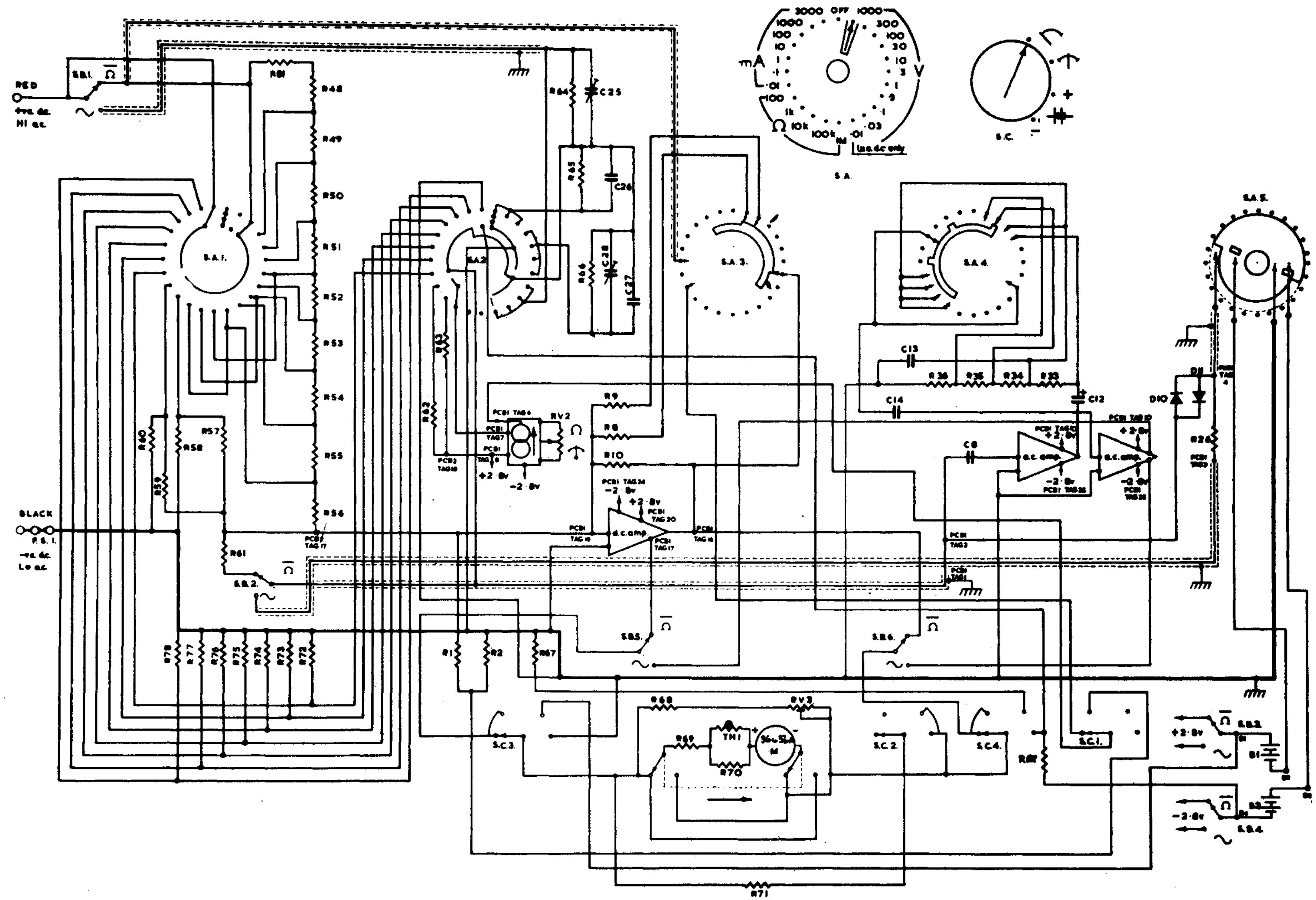


FIG. 3 A.C. AMPLIFIER CIRCUIT DIAGRAM



PCB1 - AMPLIFIER P.C.B.
PCB2 - RANGE P.C.B.

FIG. 4 INSTRUMENT CIRCUIT DIAGRAM

CIRCUIT DESCRIPTION

COMPLETE INSTRUMENT (Fig. 4 refers)

All inputs applied to the instrument terminals will be fed to the circuits via fuse FS1 which is connected directly in series with the black input terminal. This terminal is the negative terminal on dc measurements and the 'LO' terminal on ac. It is, in fact, connected via the fuse to the 'common' line for all amplifier circuits. Switch SB selects the appropriate function, either AC or DC & Ω. There are two input potential dividers, one used for ac voltage measurement, the other used during dc voltage measurement. The potential divider used during dc measurement comprises the resistor chain R81, R48 to R56 inc. The ac potential divider formed by R64 together with either R65 or R66 is connected in shunt with adjustable capacitive potential dividers to provide the necessary trimming for h.f. response.

For current measurements, the same shunt resistors R72 to R78, are used for both ac and dc. Diodes D10 and D11 provide current overload protection for the shunt resistors until currents high enough to blow the fuse FS1 are reached.

Resistors R57 to R60 inc. together with resistors R52 to R56 inc. (from the dc input potential dividers) are used as the reference resistors for the Ohms ranges. These resistors are used in conjunction with a constant current generator (shown diagrammatically in Fig. 4) together with the dc amplifier on appropriate sensitivity ranges.

Separate dc and ac amplifiers are used in conjunction with the same metering circuit. This circuit comprises the meter itself in series with thermistor TH1, its shunt resistor R70 and a swamp resistor R69. A small adjustment to the overall sensitivity of this meter circuit is provided by means of the shunt path R68 and RV3.

The group of resistors R8, R9 and R10, in conjunction with switch SA3, provide control of the sensitivity of the dc amplifier in accordance with the range in use. Similarly, the group of resistors R33, R34, R35 and R36 in conjunction with switch SA4, provide control of the sensitivity of the ac amplifier.

Resistors R67 and R82 are concerned with the battery check facility.

DC AMPLIFIER (Figs. 2 and 5)

The dc amplifier is a shunt feedback type as shown in the schematic diagram of the system in Fig. 5 below.

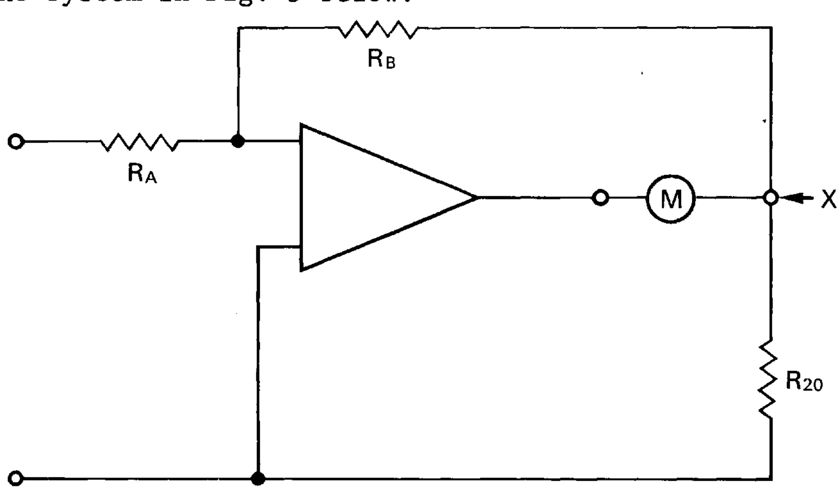


FIG. 5 SCHEMATIC DIAGRAM OF D.C. AMPLIFIER SYSTEM

The current sensitivity of the amplifier is controlled by the value of resistor R_B in Fig. 5. On all ranges except the 1000V and 300V ranges the value is fixed (R10 in the main circuit Fig. 4) and is such as to give the amplifier a sensitivity of 1µA f.s.d. The range resistors, as represented by R_A (R81, R48 to R56 inc.) are then switched in according to range, to give a constant 1MΩ/V on dc voltage measurements up to and including the 100V range. For the 300 and 1000V ranges, the input resistance R_A is left at 100MΩ and the value of R_B is modified by shunting progressively with R8 and R9 to give the appropriate overall reduced sensitivity to the dc measuring system.

The meter M in Fig. 5 represents the group of components comprising the meter, thermistor TH1, resistors R68, R69, R70 and RV3 as shown in Fig. 4 The voltage at point X (Fig. 5) is defined by the input voltage and the ratio of R_B to R_A. The current flow through the meter circuit is then defined principally by the value of R20.

Referring to the DC Amplifier Circuit Diagram Fig. 2, diodes D1 and D2 are the input overload protection diodes and VT1 is a shunt chopper transistor with its input filtered by R79, R80 and C34. The chopped dc is fed via C1 to an ac amplifier comprising VT2 and VT3. The output from this amplifier is fed via C3 into the demodulator transistor VT4. The output from the demodulator is fed via R11 and the dc amplifier comprising VT5, VT6, VT7 and VT8, to the metering circuit. Capacitor C5, connected between input and output of this last dc amplifier section, in conjunction with input resistor R11, smooths the chopped dc voltage produced at the demodulator VT4. As previously explained, overall shunt feedback is effected via resistors R8, R9 and R10.

Transistors VT9 and VT10 form the multivibrator which drives the chopper and demodulator transistors, whilst VT11 is a constant current transistor for use on Ohms measurement. The constant current output is taken from the collector and some degree of protection against the application of voltage whilst switched to Ohms measurement function is provided by R25 in conjunction with diodes D8 and D9.

<u>AC AMPLIFIER</u> (Fig. 3)

The input to the ac amplifier is via capacitors C8 and C9 and resistor R28 which, together with diodes D12 and D13, provide overload protection for the amplifier transistors. Transistors VT12 and VT13 form a high impedance input stage with almost unity gain and a wide dynamic range. The output is fed via C12 into the potential divider R33 to R36 inc. Much of the range switching is accomplished using this potential divider in conjunction with a limited amount of range switching at the input to the system. AC signals are fed back from this potential divider via C14 into the negative feedback amplifier comprising VT14, VT15, VT16 and VT17. The output from the collector of VT17 is fed via a rectifier system including D16 and D17 to provide a dc current feed to the meter circuit. Overall feedback voltage is developed across R46 and fed back to the input pair VT14 and VT15.

It will be noted that this amplifier section is dc coupled and stability of the dc conditions is ensured via path R41, R42 from the collector of VT17 back to the base of VT15. Capacitor C17 is a filter capacitor, to remove ac components from this dc feedback path.

The ac amplifier system shown in Fig. 4 is related to the circuitry in Fig. 3 as follows:

The high impedance stage VT12 and VT13 in Fig. 3 comprises the first amplifier block in Fig. 4 (with input via C8) and the second amplifier block is related to the transistor stage VT14 to VT17 inc. in Fig. 3.

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