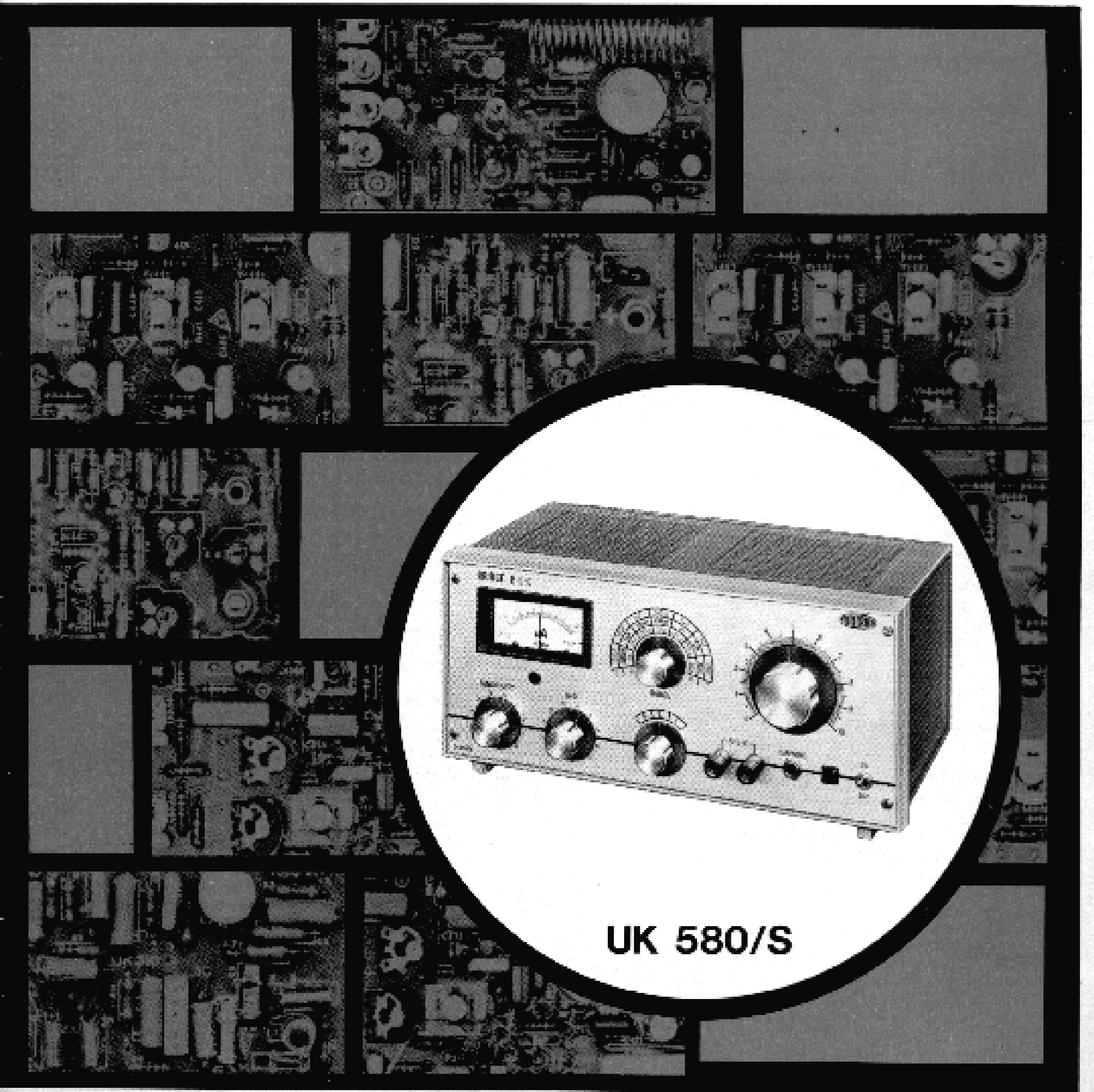
AMTRONCRAFT® KITS

L-C-R BRIDGE



UK 580/S

TYPICAL CHARACTERISTCS

Mains supply: 125 - 220 - 250 VAC - 50/60 Hz

Power consumption: 2 W

Parameters measured: resistance (R), inductance (L), capacitance (C)

Measurement ranges: seven decades for each parameter graduated in hundredths

Accuracy: 0.5%

Resistance measurement: from 0.1 Ω to 1 MΩ

Capacitance measurement: from 5 pF to 100 μF

Inductance measurement: from 10 μH to 100 H

Active components: TBA820-T - FU6 A7776393 - L141B1

Diodes: 8 x 1N4002 - 6 x BAY71 - OA95

Zener diodes: 2 x 1ZS13A or 1ZS12A

Dimensions: 280 x 150 x 120 mm

Weight: 1.75 kg

This instrument enables very precise measurements to be made on resistance, inductance and capacitance. The high accuracy is due to the measurement being carried out by bridge methods, a different bridge is used for each parameter. Bridge balance is shown on a centre-zero meter, whose sensitivity is increased using integrated operational amplifiers. An ingenious idea limits the gain of large signals, but increases the gain for small signals that occur near balance. For alternating current measurements (L and C) the bridge is excited by a very stable oscillator, also made using an integrated circuit. In addition, the signal is further amplified, when AC is used, with a selective operational amplifier, active filter). The AC signal can also be detected by listening to it with earphone or looking it on an oscilloscope; a suitable socket is provided for this.

The layout of the controls makes the measurements both quick and easy.

A suitable control enables the resistive component to be neutralized during measurements on reactive devices.

Although the adjustment are a little more complex than a normal tester, a bridge yields results that are incomparably more accurate; in fact, for many years the bridge has been the principle measuring instrument and is also used for calibrating other instruments. The advantage of a bridge over other types of instruments is that its accuracy does not depend upon a calibration that is made from time to time, but it is as precise as the ratio elements used for balancing it. A similar comparison can be made between spring scales and a balance using weights.

The indicator on the front panel does not have to make a quantitative measurement, but only has to show when the bridge is in balance, or in other words, when the current passing through it is zero. It must only be sensitive.

This fact has been taken into account in designing the UK 580/S, in a very efficient way; the signal is amplified before sending it to the meter. The amplifiers are the very latest integrated circuit operational amplifiers and are designed to have all the requisites that a measurement amplifier needs: high input resistance and low output resistance, high stability, high gain over a wide frequency range.

The combination of three types of bridges into a single unit enables the true values of resistors, inductors and capacitors to be found with excellent precision.

In the design of filters, bias networks, etc., a component of a given value is not so often needed; what is more important is to know its true value and to base the design on that.

Certain elements change their value with time and one must always be able to check them to see if they are within their tolerance. In the case of inductors which the hobbyist often winds himself, it is very important that he can measure their effective value, because an exact formula to calculate it does not exist.

Measurement bridges are classified according to their accuracy and their basic circuit. The accuracy depends upon the ratio elements used and upon the sensitivity of the zero indicator. The circuit is chosen from those available on the basis of the magnitude of the parameter being measured. There are bridges that work with direct current and measure resistance; there are bridges that work with alternating current and measure reactances. Inductance and capacitance are reactances: they cannot be measured with direct current because a variable voltage, not a constant voltage has to be applied to make them exhibit their characteristics.

An ideal inductor behaves as a short circuit to a direct current, while a capacitor behaves as a perfect insulator. Many components are a long way from having an ideal behaviour and a loss component must be taken into account when measuring them; this component is resistive in nature. In a practical case, an inductor is usually formed from a coil of copper wire; copper is an excellent conductor, but it always has some resistance. The smaller this resistance, the higher is the inductor's magnification factor or Q.

In the case of capacitors, the perfect insulator does not exist and there is always leakage current, even in a good quality capacitor. It, however, has little influence, and, except in certain applications, the leakage can be ignored. The measuring circuits, using AC, in the UK 580/S have suitable systems for eliminating the influence of losses on the accuracy of measurement.

In practice, the effective value of an inductor or a capacitor is composed of two components. By convention, one is called the «real» component and the other is called the «imaginary» component. The real component corresponds to the resistive loss and the imaginary component defines its property towards alternating current.

As the frequency is increased, the influence of the loss is felt more and more; this is especially true for the case of an inductor where the «skin effect» tends to reduce the useful cross sectional area for the passage of current, so increasing the conductor's resistance. The amalgamation of the real and imaginary part of a reactive component forms the effective resistance to the passage of an alternating current. This quantity is called impedance and it is measured in ohms. The theorem of Pythagoras is used to find the resultant of the resistive part and the reactive part, supposing these two vectors to be perpendicular to each other. The resistance of a lossless capacitor or inductor to an alternating current is respectively called a «capacitive reactance» (X_C) and an «inductive reactance» (X_L). Both depend upon frequency, but directly in the case of an inductance and inversely in the case of a capacitance. In simpler words, it may be said that the higher the frequency, the greater an inductor resists the passage of current, while a capacitor behaves in the opposite way. These properties are very much used to make circuits whose behaviour depends upon frequency, in other words filters.

Basic bridge circuits

All bridges, whether DC or AC, fundamentally depend upon the balancing of the output voltage, which should be zero. All are derived from the original Wheatstone Bridge, which is still used today for measuring resistance.

A Wheatstone bridge, shown in fig. 2, consists of:

1) Four resistive arms connected in a diamond shape, that include the unknown resistor and the reference resistor.

2) A source of alternating direct current, as required.

3) An output indicator, which could be a galvanometer, earphones, or an oscilloscope.

According to the use to which it has to put and to the various arrangements used, the name of the bridge changes, the total layout is always clearly derived from the Wheatstone bridge.

In the equipment's description, we shall give all the informations needed to separate the functions of the various

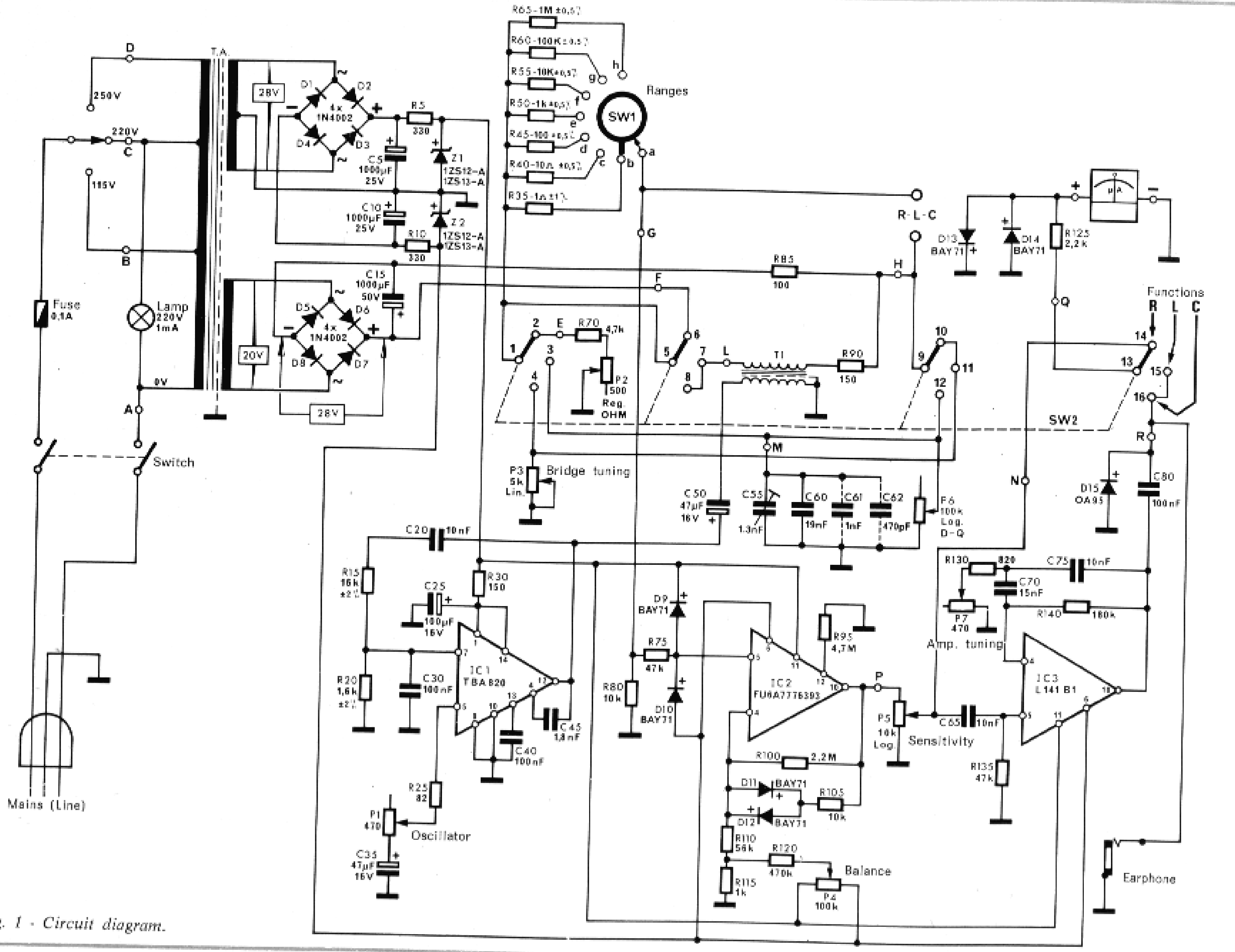


Fig. 1 - Circuit diagram.

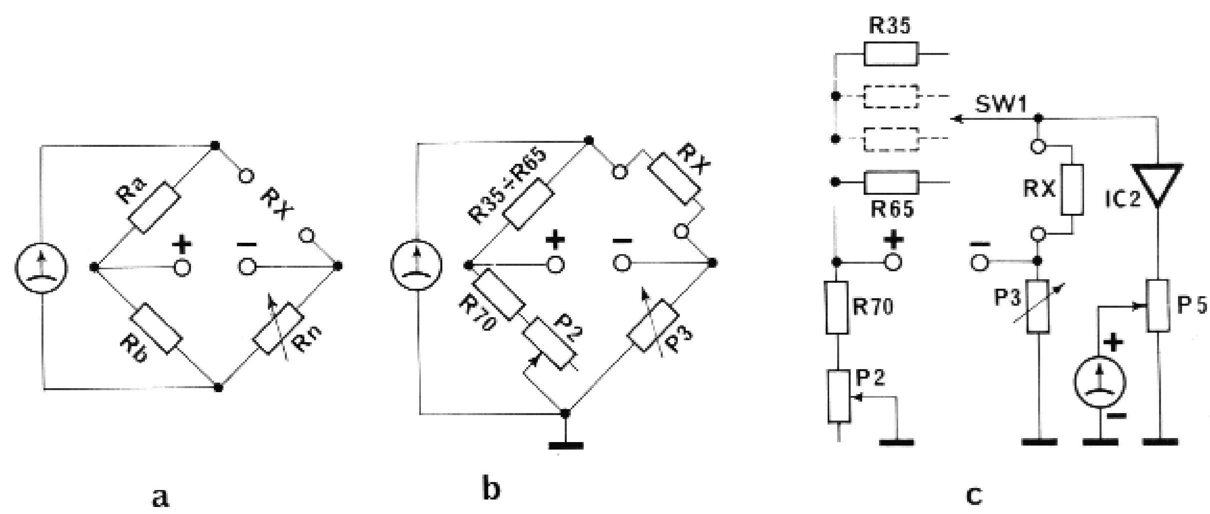


Fig. 2 - Resistance measurement.

elements as well as the system used to connect up the element that is to be measured.

CIRCUIT DESCRIPTION

The arrangement of the measurement bridge is changed by a switch (SW2) so it can form three completely different circuits according to whether R or L or C is to be measured. First of all we shall give everything needed underst-and how the three different bridges work, starting with the circuit elements and finishing with the theoretical cir-cuit of the bridge under discussion.

Resistance measurement (fig. 2)

The well-known Wheatstone bridge is used. The four arms are formed from, respectively, the resistor being measured, potentiometer P3, resistor R70 in series with potentiometer P2 and the standard resistor which is one of the group comprising R35 - R65 and which can be selected by swit-ch SW1 (fig. 2C).

Instead of the usual galvanometer across one of the bridge's diagonals, we have a meter connected to an operat-ional amplifier. This amplifier has a feedback network which fixes a 32 dB gain both for DC and for AC (used for later measurements). This is true only for very small voltages; if there are larger voltages, a supplementary feedback network comes into operation. The network is formed by D11 and D12 in series with resistor R105. When the diodes conduct, the gain is reduced in proportion to the signal level. This idea has been used to eliminate the need for a push button to increase the bridge's sensitivity; a method that has been used up to this moment. This idea was used because a strong unbalance could produce an excessive signal that could damage the meter. Once upon a time, an approximate balance had to be sought using the instrument with its sensitivity suitably reduced. At a cert-ain point a button was pressed and this restored its sensitivity to maximum.

The system described however elimi-nates the need for a double sensitivity instrument. A control using P5 at the operational amplifier's output adapts this output to the meter's scale.

Since the formula for the balanced condition of a Wheatstone bridge is:

$$Rx = \frac{Rn\ Ra}{Rb} \qquad \text{(fig. 2a)}$$

it can be seen that only the product Rn Ra needs to be changed to cover a huge range of resistor values, while Rb remains constant.

Rn is formed by a group of high precision, high stability fixed resistors, which are numbered from R35 to R65 on the circuit diagram. These resistors can be selected by a rotary switch. The parts left empty by the various switch-ed steps are filled in by potentiometer Ra (P3 in the circuit diagram). A con-tinuous coverage of the bridge balance is possible by adjusting this potentio-meter; the value introduced into the circuit by the potentiometer behaves as a multiplication factor, not as a sum that to be added. The variation of this potentiometer must be **perfectly linear** and it must have excellent stability aga-inst temperature variations, otherwise the values shown on the scale will tend to deviate from the true ones. Rb in-cludes a preset potentiometer P2, in se-ries with the main resistor. This poten-tiometer is for zeroing the bridge balance so that the scale of P3 is not displaced. The zeroing is achieved using a **stand-ard resistor** of 1000 Ω ± 1% that is supplied with the instrument.

The calibration carried out using this resistor is valid for all the positions of the bridge, within the allowable tolerances.

The DC supply to the diagonal of the bridge is taken from the secondary of the power supply transformer. From there it is rectified by the bridge D5, D6, D7 and D8 and smoothed by C15. This voltage does not have to be well stabilized because, as was seen in the formula, its value does not enter into the accuracy of the measurement. It only influences the instrument's sen-sitivity but this is already very large and it can also be adjusted by potentiome-ter P5. The power supply furnishes a voltage of about 25 V and a current of 100 mA maximum. It will be explained in more detail later that the operational amplifier for resistance measurement, together with other parts, is powered from another section of the transformer secondary. This voltage is rectified by the bridge D1, D2, D3 and D4, smooth-ed by C5 and C10 and then stabilized by zeners Z1 and Z2, respectively in series with resistors R5 and R10.

Operational amplifiers need a positi-ve and a negative supply with centre ground and the voltages must be abs-olutely stable. The power supply volt-ages are given by the voltages of zeners Z1 and Z2.

Inductance measurement (fig. 3)

We have already said that reactive components must be measured with alternating current. The first thing that is different from the preceding diagram is that the DC voltage across one diago-nal is substitued by a fixed alternating voltage (about 1000 Hz).

The frequency of 1000 Hz has been chosen because it is the standard used for measuring various quantities at low frequency, for example, the impedance

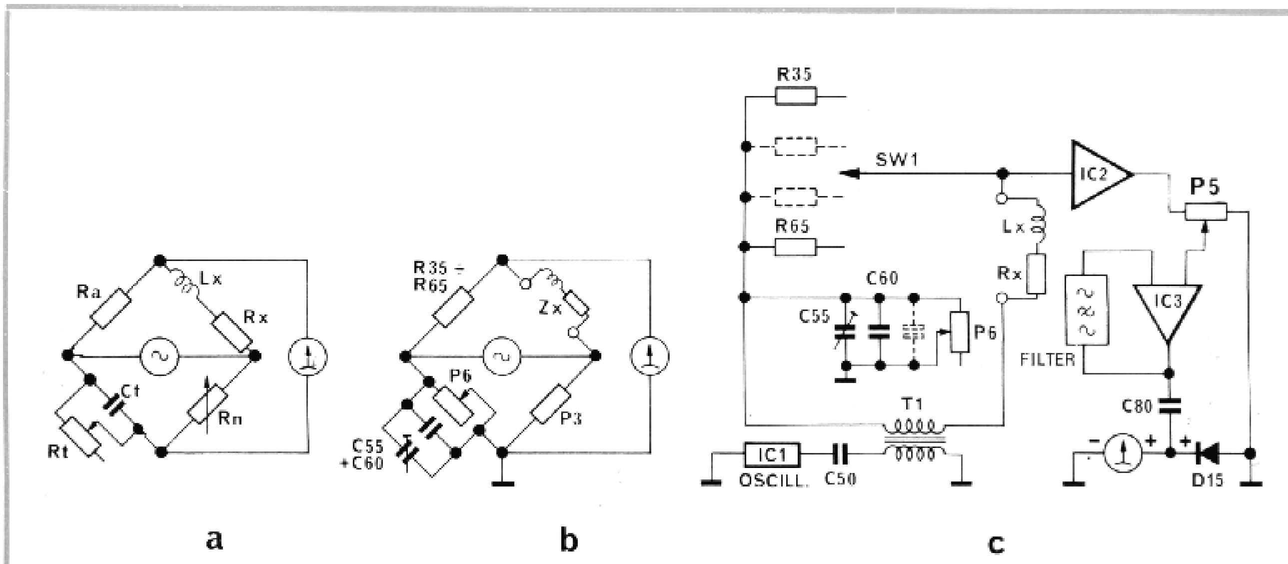


Fig. 3 - Inductance measurement.

of the coil in a loudspeaker. It should be remembered that the measured value of an inductor is valid for any frequency. The magnification factor, Q, however is not constant with frequency and so a scale for this quantity has not been incorporated. All that has been done is to put in an uncalibrated control that balance out the resistive (or real) part of the inductor so that the reactive (or imaginary) part can be measured with greater precision. A proper instrument exists for measuring the magnification factor; this is the Q-meter which carries out the measurement at the frequency at which the coil is intended to work. In fact the Q, or magnification factor, or damping coefficient depends upon too many things connected with coil construction to be able to extrapolate it from a frequency that differs from the operating frequency.

Another difference with respect to the resistive bridge is that a further amplification stage is used; this is a selective operational amplifier IC3 which acts upon the signal taken from the first diagonal of the bridge.

The zeroing signal is alternating and it must first be rectified before going to the meter, which works in DC. This is done by the circuit formed by diode D15 and capacitor C80.

The bridge shown in fig. 4 is called a Marxwell Bridge.

The elements used for balancing the bridge are the same as those used for the Wheatstone bridge (i.e. P3 and the decade group including the resistors from R35 to R65).

The scale adjustment is carried out by P6 which has one or more capacitors to balance the reactive part. One of these capacitors is variable and is used to adjust the zero on the P3 scale in the same way as was carried out for resistance measurements using P2. P6 is brought out on the front panel and is used to balance out the resistive part. The inductance reading will be correct only when the resistive component is exactly balanced out. If this is not done, the minimum reading will correspond to a different value that depends upon the impedance, that is the square root of the sum of the squares of the resistance and the reactance at 1000 Hz.

It is therefore very important that P6 and P3 are alternately adjusted, during inductance measurements, until the smallest minimum is obtained.

The bridge is driven by an oscillator whose active element is the linear integrated circuit IC1. This oscillates due to the feedback signal arriving at its non-inverting input after passing through the Wien bridge filter formed by C20, R15, R20 and C30. The oscillation frequency also depends upon the gain of the active element which can be adjusted within certain limits using P1.

The equation for the Maxwell bridge is:

$$Lx = Rn\ Ra\ Ct \qquad \text{(fig. 3a)}$$

As in the preceding case, the balance depends upon the product of Rn and Ra, therefore the same considerations apply in this case.

Rx (shown in series with the inductor in fig. 3 depends upon the multi-balanced out and so eliminated by the adjustment of Rt or potentiometer P6.

The advantage of this bridge is that the inductance does not have to be compared with a standard of the same type, but with a reactance of the opposite sign, that is, a capacitance.

Capacitance measurement (fig. 4)

Although in concept it is analogous to that of inductance, the measurement of capacitance needs a different circuit in which it is compared with a reactance of the same type. The type of bridge used is called a «de Sauty Bridge». In this case the leakage current of a capacitor is considered as if it passes via a resistor in parallel with an ideal capacitor. Note that the bridge is always balanced by the same elements, that is, with the decade unit R35 to R65 and potentiometer P3; they are, however arranged in a different way in the diamond of the bridge.

Other components that are the same as the preceding case are capacitor unit C55-C60 **(and any other components added to zero the scale)**, in parallel with potentiometer P6 for balancing out the resistive component. The calibration is also valid for inductance so the **calibration simply has to be carried out using the standard capacitor of 1000 pF ± 1%** supplied with the kit.

In the case of a capacitor, it is usual that the resistive component is of less importance than with an inductor; so although the same procedure is used, potentiometer P6 does not have to be used so much.

In this case the bridge equation is the following:

$$Cx = \frac{Rn\ Ct}{R} \qquad \text{(fig. 4a)}$$

This time we do not have the product of Rn and Ra, but their ratio; it will be seen that the capacitance scale is in the reverse direction to that of the resistance and the inductance.

PERIPHERAL CIRCUITS

We have already spoken about the operational amplifier inserted between the bridge's output and the meter.

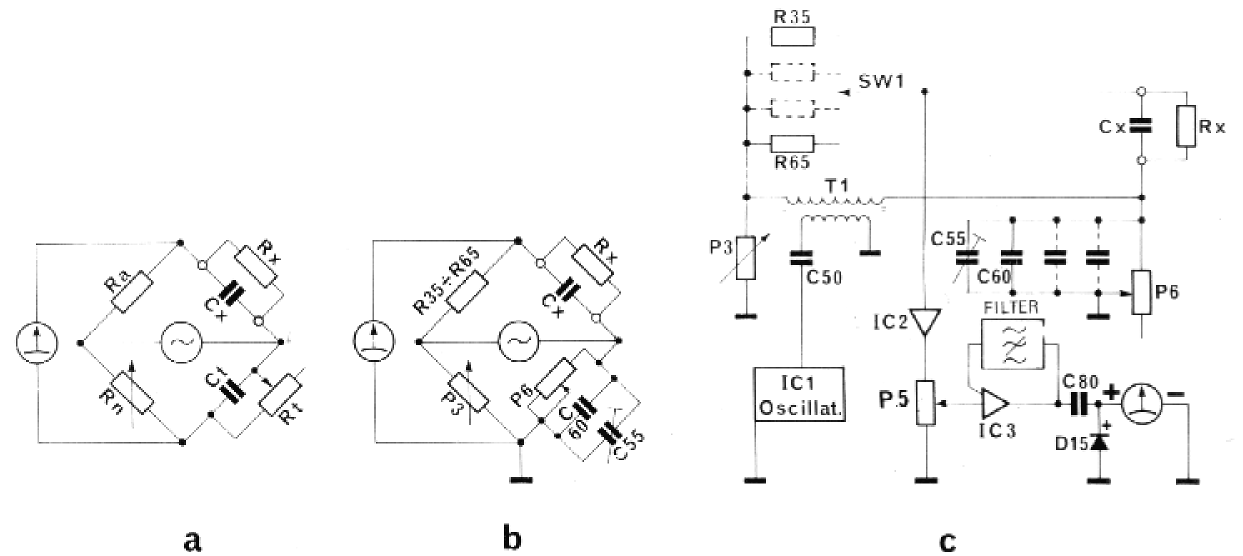


Fig. 4 - Capacitance measurement.

When the two diodes D11 and D12 enter full conduction, because of a very strong signal, the feedback resistance R105 becomes equal to the input resistor R80. Now the gain of an operational amplifier depends on the ratio of these two resistors; thus if the ratio of the resistors is one, the gain will also be 1, or in other words, we have a voltage gain of 0 dB. Naturally, there is also current gain due to the different values of the input and output resistors across which the voltage is developed. The first is very high and thus the input current is very low; the second is very low and inversely, the current will be large. There is an overload protection at the input of the integrated circuit; diodes D9 and D10 carry out this work by preventing the input voltage from exceeding either the positive or negative supply voltage.

Both the AC bridges are driven by transformer T1, which is constructed in a special way, — it has a pot core to avoid stray flux and there is an electrostatic screen (connected to ground) between the primary and secondary windings to avoid asymmetric capacitive coupling that may alter the accuracy of the measurement.

The alternating signal exciting the bridge is generated by a sine-wave oscillator that is very stable against load variations; this is due to the low output impedance of the operational amplifier that is the active element of the circuit.

Another integrated circuit (IC3) is used to selectively amplify the signal coming from the wide-band amplifier IC2.

The circuit, of which IC3, is a part, is an active filter; it both selects a certain frequency and it amplifies it. The frequency is selected by R140, C74, R130, P3 which forms a rejection filter in the feedback, this has the effect of increasing the output by increasing the Ω and hence the selectivity and the maximum voltage gain.

The filter is a «bridged T» type.

Potentiometer P7 alters the centre frequency of the filter so it can be tuned in exactly to the oscillator's frequency and hence increases the sensitivity of the null or zero detector.

The meter is protected agains overloads by the pair of diodes D13 and D14.

The human ear is a very precise measuring device, much more so than a meter, so an earphone plug is provided for precise null measurements when an alternating current is used for the bridge drive. The bridge is balanced when the whistle disappears.

(Should there be some uncertainty over the zero point, an oscilloscope can be connected and the bridge zeroed for minimum residual signal).

The complete instrument is powered by the mains (line supply) and it can be used with three different voltages. There is a selector switch to accommodate these three voltages (115, 220 and 250 VAC).

The supply frequency can be either 50 Hz or 60 Hz. An on-off switch breaks both paths from the plug, thus it is immaterial which wire is connected to neutral and which to the live pin.

A fuse protects the supply from any faults that may occur in the instrument and an indicator lamp shows when the apparatus is switched on. The plug also has an earth pin.

MECHANICAL CONSTRUCTION

The universal bridge is contained in one of the new line metal of instrument cases, which already includes many types for a multitude of electrical and electronic measurements.

Most of the circuit is mounted on a single printed circuit board; it looks neat and its characteristics do not vary from one assembly to the other. In addition, a printed circuit board eliminates wiring errors, which once were very common.

All the controls needed for the bridge are mounted on the front panel; these are:

1. The meter for detecting zero current in the measurement diagonal of the bridge.
2. The sensitivity control that adjusts the amount of current flowing through the meter si it is not overloaded.
3. The D-Q control for neutralizing the loss component when measurement inductors and capacitors.
4. The range selector.
5. The balance control P3 which determines the precise value of the component (the rough value has already been selected on the range switch).
6. The function selector, which is changed according to the type of component being measured (resistor, inductor, or capacitor).
7. The socket for connecting the component being measured.
8. The earphone socket; this is very useful for an exact zero when alternating current is being used.
9. The indicator lamp to show when the instrument is switched on.
10. The mains (line) switch.

On the rear panel are the supply cable with earthed plug, the protection fuse and voltage selector.

ASSEMBLY

Assembly should be carried out with great accuracy if the instrument is to reach its optimum performance. As an aid to this task, fig. 5 shows the transparent print of the PCB tracks with the exact arrangement of the components superimposed. This arrangement is also screenprinted on to the components side of the PCB itself so that the various mounting points can be easily identified.

First some practical hints to bear in mind. Every printed circuit board has a side carrying the copper connecting tracks — the copper side — and a side for the mounting of the components. The components are mounted in contact with the surface of the printed circuit board, and parallel to it. (For certain vertically mounted components special mention will be made in the course of these instructions). Integrated circuits should be inserted into their sockets in the correct sense, and care should be taken not to bend their connecting pins.

For the other components, bend over their leads so that they fit exactly into the appropriate holes in the PCB. Take care not to damage the point at which the lead wire joins the components. Check the exact position of each component against fig. 5, and insert the lead wires through the appropriate holes. Polarized components have to be mounted in the correct sense, and when we are dealing with these, specific mention will be made in the instruction.

Soldering is carried out using a medium power soldering iron. Soldering should be quick and precise so as to avoid overheating the components and causing permanent damage to their characteristics. The amount of solder used should be just enough to ensure a good solder joint. Should a joint be unsuccessful at the first attempt, allow the component to cool down before trying again. An imperfect solder joint is one which is «dry» or does not guarantee perfect electrical contact between the parts that it must join.

A poor joint is dark in colour and its edges do not «wet» the surface that it touches; in fact it looks like a drop of water on a waterproof or greasy surface.

Special care should be taken when soldering semiconductor components, such as diodes and zeners, because excessive heat conducted along the leads may permanently alter or destroy the semiconductor's characteristics.

Once the soldering has been completed, andy lead wire protruding more than 2 or 3 mm from the copper surface should be cut away with cutting nippers. Care must be taken not to create bridges between adjacent tracks during soldering.

IMPORTANT

Do not use soldering pastes or deoxidizing acids to aid the soldering.

The de-oxidant contained in the cored solder is sufficient to make a perfect

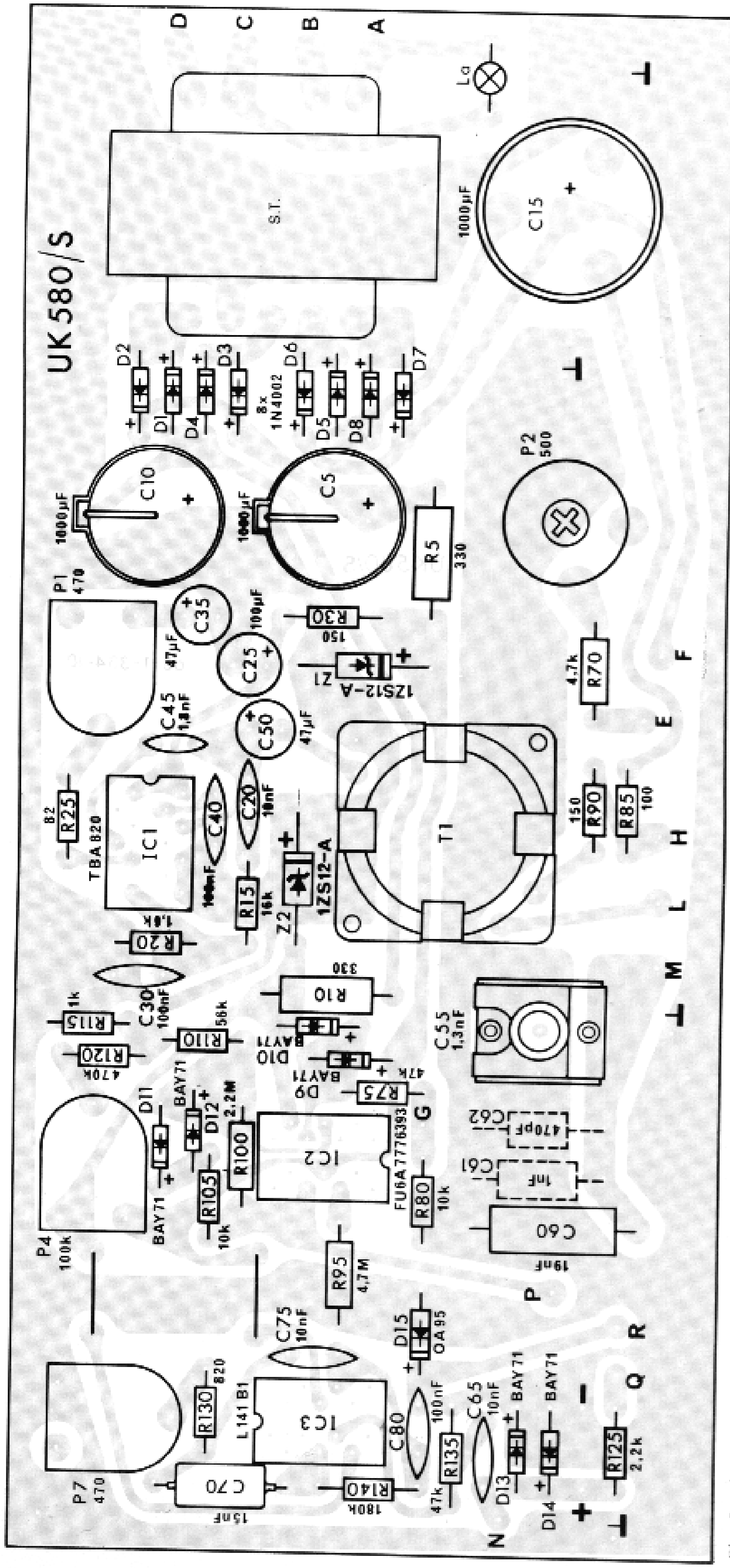


Fig. 5 - Arrangement of the components on the printed circuit board.

soldered joint. Other types of de-oxidants can reduce the insulation between tracks and can also corrode the metallic parts with time, even when sold. The only de-oxidant permitted in electronics is rosin. If a contact is so oxidized that it cannot be soldered — a rare phenomenon — it is best to scrape it with a file or emery cloth until fresh metal is exposed.

Remember that the use of our assembly instructions is a guarantee that the result will be perfect. Each assembly step has a square printed next to it; every time an operation is carried out, put a tick in that square.

After each assembly step a thorough check should be carried out. Trouble taken at each stage may well allow an error to be spotted which could otherwise involve hours of investigation to identify the fault. There is also the risk of having to replace damaged components.

STEP ONE - Assembling the components to the PCB - fig. 5

☐ Following the instructions given above, mount on the printed circuit board resistors R5, R10, R15, R20, R25, R30, R70, R75, R80, R85, R90, R95, R100, R105, R110, R115, R120, R125, R130, R135, R140. Some of these resistors have greater dissipation than others and are indicated by larger rectangles in the diagram.

☐ Mount the two bare wire links indicated by straight lines in the upper left-hand corner of the PCB.

☐ Mount the following terminal pins: 4 pieces marked ⊥; 16 pieces, respectively, A, B, C, D, E, F, G, H, L, M, N, P, Q, R, +, −; 2 pieces for the indicator lamp LA; 4 pieces for possible future connection of capacitors C61 and C62 — which connection will be determined at the calibration stage. These terminal pins are composed of a tubular part and a pin separated from the tube by a shoulder. The tubular part is mounted on the components side of the PCB to receive the end of the connecting wire. The pin is inserted through the appropriate hole, soldered to the copper pad and trimmed as in the general instructions.

☐ Mount the two polyster capacitors C60 and C70.

☐ Vertically mount electrolytic capacitors C5, C10, C15, C25, C35, and C50. These are polarized components and care must be taken to mount them with the correct orientation, making sure the positive terminal, which is indicated by a case marking, corresponds with the hole marked + on the PCB. In case of doubt, or if the printed is not legible, bear in mind that the negative terminal is the one directly connected to the aluminium case of the capacitor.

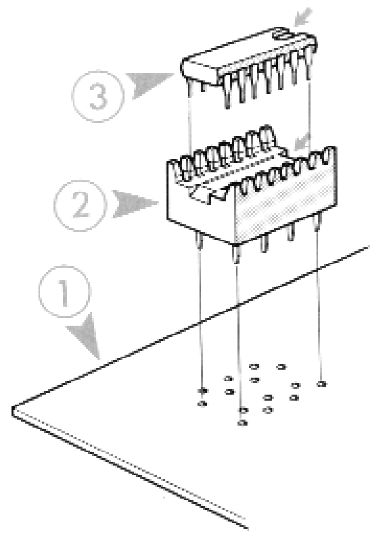


Fig. 5/a Mounting an integrated circuit in its socket.

Japanese electrolytic capacitors are marked at the negative terminal.

☐ Mount diodes D1, D2, D3, D4, D5, D6, D7, D8, D9, D10, D11, D12, D13, D14, D15 and zener diodes Z1 and Z2, checking that the device numbers correspond with the numbers printed on the PCB. Diodes and zeners are polarized components and the positive terminal can be identified by a ring printed round the case. This terminal should be inserted through the hole marked + on the PCB.

☐ Mount the socket for integrated circuits IC1, IC2 and IC3. Make sure the keying slot at one end of the soket coincides with the appropriate mark on the PCB.

☐ Mount the four trimmer potentiometers P1, P2, P4 and P7.

☐ Mount capacitive trimmer C55 ensuring that the tab from the control is connected to ground.

☐ Mount transformer T1, soldering its terminals to the copper tracks. Orientation is made easy by the fact that there are three terminals on one side of the component, and only two on the other.

☐ Mount supply transformer ST passing its terminal wires through the appropriate holes in the PCB. Mechanically fix by inserting the two lugs on the cover through their slots in the board, giving them a greater turn with pliers, and soldering to the ground track.

Now referring to fig. 5a

☐ Mount the three ICs (3) in their appropriate sockets (2) ond the PCB (1).

1. Check their position, comparing the number printed on the IC case with those given in the diagram;
2. Check their orientation, making the keying slot of each IC match the slot in its socket;
3. Take great care not to bend or damage the IC pins when inserting them.

STEP TWO - Preparing the range selector switch - fig. 6

This switch consists of an insulated support wafer and, some distance away from it, a one-way, seven-position switch wafer. The resistances, which are all very close tolerance, are mounted with one terminal soldered to a switch contact and the other to the insulated contact immediately above. The wiper contact (a) of the switch is not connected at this stage. In the figure the resistors are shown with different lead lenghs for the sake of clarity, but in practice the leads should be kept as short as possible.

☐ Mount resistor R35 (1) at terminal b.

☐ Mount resistor R40 (2) at terminal c.

☐ Mount resistor R45 (3) at terminal d.

☐ Mount resistor R50 (4) at terminal e.

☐ Mount resistor R55 (5) at terminal f.

☐ Mount resistor R60 (6) at terminal g.

☐ Mount resistor R65 (7) at terminal h.

☐ Use a length of bare wire (8) to connect together all the terminals of the support wafer to which resistors are connected. Point 2 will later be used to connect the common point of the resistors to the rest of the circuit.

STEP THREE - Preparing the function switch - fig. 7

This switch will be seen to consist of two separate sections each being a two-way three-position element. They are assembled on opposite sides of the same wafer as indicated in the figure by «view from side A» and «view from side B». The numbers corresponding to the terminals are established by counting from the mounting screen position. All the connections are made with stiff bare wire and should be carried out in an orderly fashion so that they do not touch each other or come into contact with metal parts of the switch or the surrounding assembly. The connections should be carried out in the following order.

☐ Link (1) from terminal 1 to terminal 5.

☐ Link (2) from terminal 7 to terminal 8.

☐ Link (3) from terminal 4 to terminal 10.

☐ Link (4) from terminal 10 to terminal 11.

☐ Link (5) from terminal 3 to terminal 12.

☐ Link (6) from terminal 15 to terminal 16.

The positions of the terminals should be remembered, perhaps by marking them with a felt-tip pen, since other connections will later be made to them.

STEP FOUR - Rear panel assembly - (fig. 8)

☐ Mount the fuseholder (2) on the rear panel (1), locking in with the knurled ring (3).

☐ Insert the fuse (4) in the holder and screw on the cover (5).

☐ Pass the supply cable (6) through the panel allowing about 15 cm free on the inside of the case. Lock the cable with clamp (7).

☐ Mount the voltage selector (8) with screws (9) and nuts (10), as shown in the diagram.

STEP FIVE - Assembling the base - (fig. 9)

☐ Mount the two feet (6) on the base (1) using clips (7).

☐ Stick a felt pad (8) to each foot, having removed the protective paper from the adhesive.

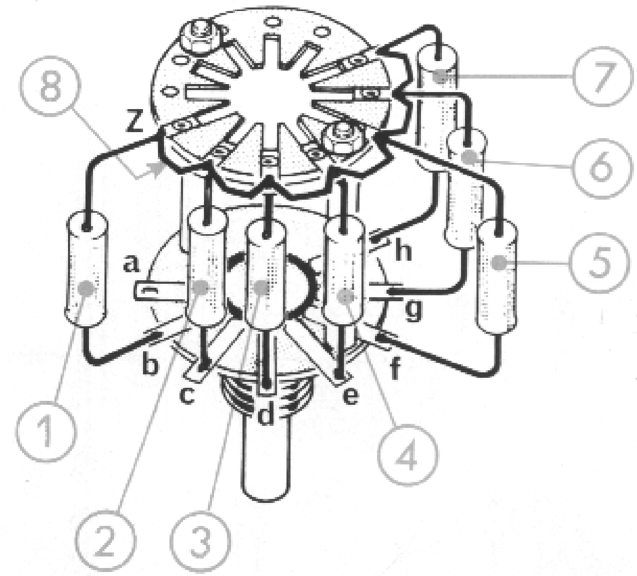
☐ Mount the six hexagonal spacers (3) in the correct holes in the panel (1) and fix them with screws (2).

☐ Mount the completed PCB (4) on these spacers and lock it in position with screws (5).

STEP SIX - Assembly of the front panel - (fig. 10)

☐ Prior to assembling the panel, remove the protective film.

☐ Mount the mains toggle switch (2) adjusting the lock-nut so that the threaded part sits just proud of the nut (5) when the spring washer (4) has been inserted and the whole assembly tightened up.



1 1 Ω wire-wound resistor ± 1% between terminal b and the corresponding terminal above it
2 10 Ω resistor ± 0.5% between terminal c and the corresponding terminal above it
3 100 Ω resistor ± 0.5% betweeen terminal d and the corresponding terminal above it
4 1 kΩ resistor ± 0.5% between terminal e and the corresponding terminal above it
5 10 kΩ resistor ± 0.5% between terminal f and the corresponding terminal above it
6 100 kΩ resistor ± 0.5% between terminal g and the corresponding terminal above it
7 1 MΩ resistor ± 0.5% between terminal h and the corresponding terminal above it
8 Stiff wire connecting together the upper terminals of the switch

Fig. 6 - Preparing range selector switch SW1.

☐ Mount potentiometer P3 (6) as shown, with spacer (7) and washer (8) introduced between the body of the potentiometer and the rear of the panel. Tighten up with nut (9).

☐ Press the indexed disc (10) into position on the milled part of the knob (11). Mount the knob on the shaft of the potentiometer and lock it in position with the grub screw, taking care to align the index mark with the red mark on the scale just before the zero. This should be done with the potentiometer shaft rotated fully anticlockwise.

☐ Mount the red signal neon (12) by pressing it through the panel into the locking clip (13).

☐ Mount jack socket (14) with spacer (15) introduced between it and the panel (1). Lock it in position with nut (16).

☐ Mount the terminals (17) (black) and (18) (red) using the following procedure for both:

a) Place the locating insulator (18) over the threaded shaft of the terminal.

b) Insert both in the hole in the panel.

c) Fix the insulating washer (19) which should mate with the recess on the insulator (18).

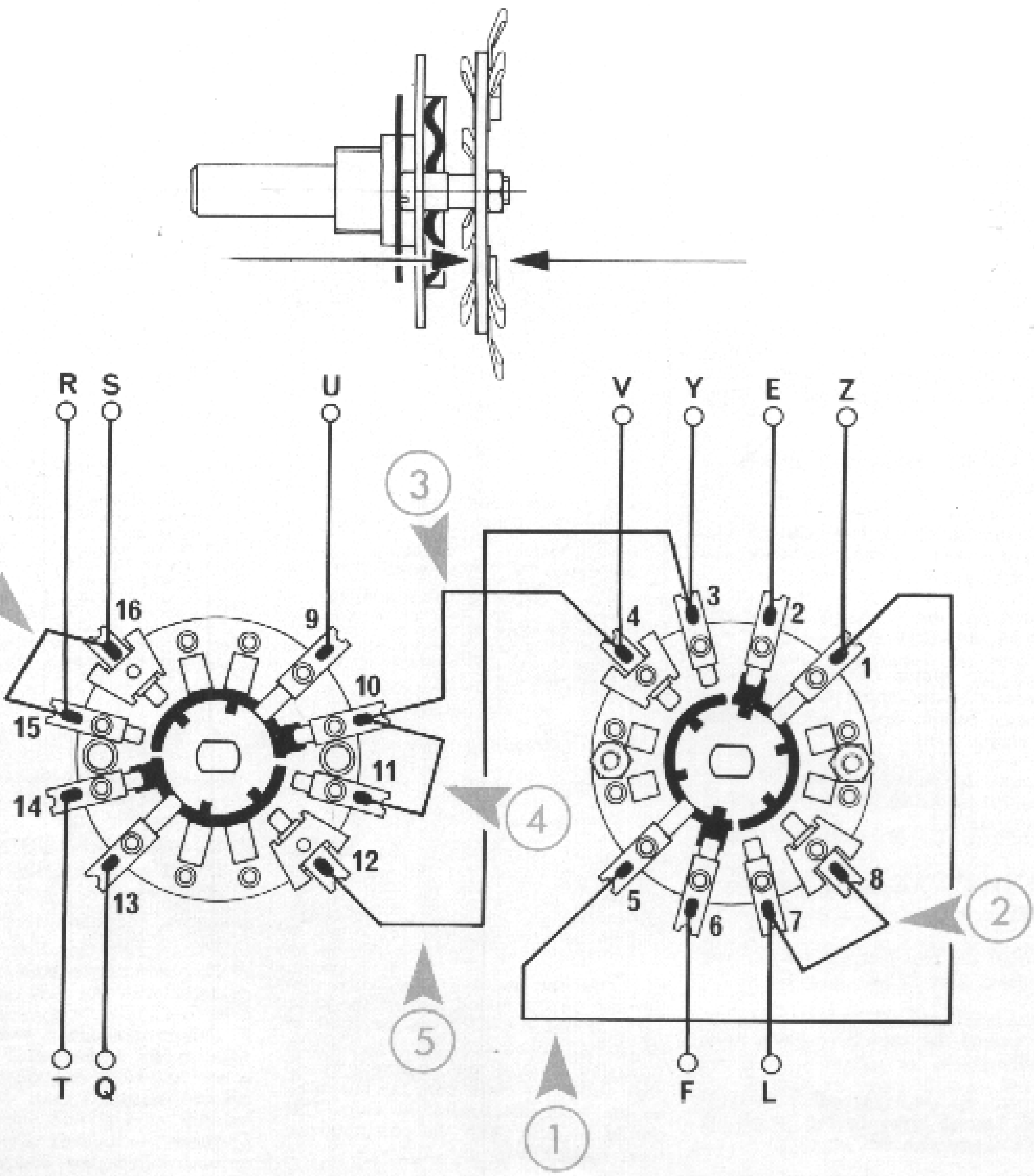
d) Locate the plain washer (20) and lock it with nut (21).

e) Locate eyelet terminal (22) and lock again with nut (23).

☐ Mount the function switch SW2 (25) with spring washer (26) inserted between the switch and the panel. Tighten up with nut (27).

☐ Press the indexed disc into position on the milled part of the knob (28). Mount the knob on the shaft of the switch and lock it in position with the Allen-head grub screw, using the Allen key provided. Check that at its three positions the index mark corresponds to one of the letters R, L and C screen-printed on the front panel.

☐ Mount the completed switch SW1 (29), inserting as before a castellated washer between it and the rear of the front panel. Use the appropriate nut to tighten up in the hole marked RANGE. Fix the knob in the same way as before, checking that for each of the seven positions of the switch the index line is exactly at the half-way point of one



1	Stiff	wire	from	contact	1	to contact	5
2	Stiff	wire	from	contact	7	to contact	8
3	Stiff	wire	from	contact	4	to contact	10
4	Stiff	wire	from	contact	10	to contact	11
5	Stiff	wire	from	contact	3	to contact	12
6	Stiff	wire	from	contact	15	to contact	16

Fig. 7 - Preparing the function selector switch.

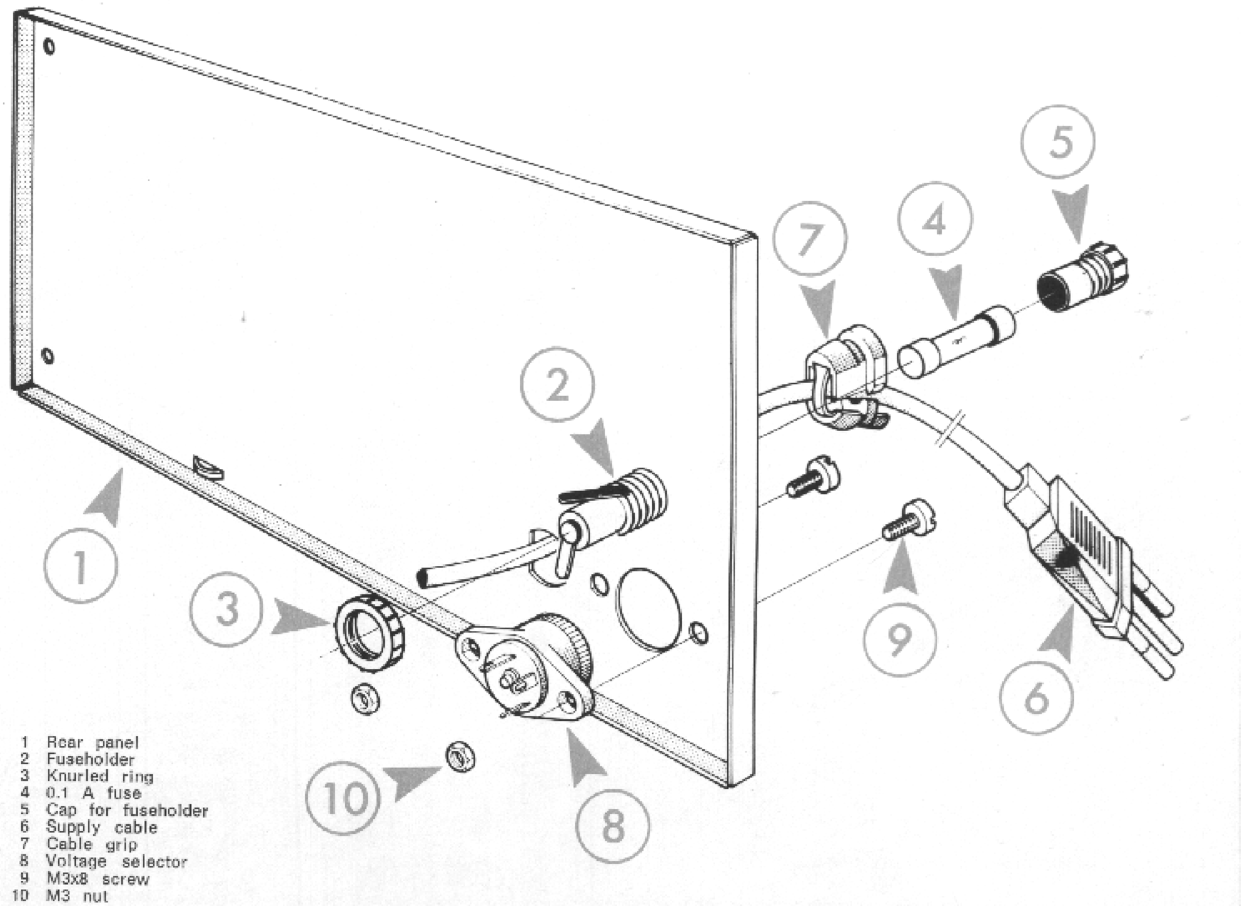


Fig. 8 - Assembling the rear panel.

of the seven sectors showing the measurement ranges.

☐ Mount potentiometer P5 (30) at the hole marked SENSITIVITY on the front panel. Of the two nuts supplied with the potentiometer, (31) acts as a spacer, and (32) is for tightening up. Press the indexed disc (33) into position on the milled part of the knob (34). Mount on the potentiometer shaft so that the rotation of the potentiometer corresponds to the scale marked on the front panel. Tighten up with the Allen key provided.

☐ In the same way mount potentiometer P6 (35) through the front panel hole marked D-Q.

STEP SEVEN - Mounting the microammeter - (fig. 11)

Fit frame (2) through the rectangular space in the front panel (1).

☐ Place the instrument (3) on the rear of the front panel (1) so that its upper edge rests against the upper flange of the frame (2).

☐ Fix the two fixing plates (4) over the fixed bolts of the instrument so that their tongues engage in the slots prepared for them in the side flanges of the frame (2).

☐ Tighten up the plates (4) to the instrument by means of four nuts (5).

☐ The instrument is fixed in place on the panel by screwing the four screws (6) into the threaded holes provided for them in the back of the panel (1).

☐ Fit the two eyelet terminals (7) over the two electrical contacts of the instrument and fix with nuts (8).

STEP EIGHT - Wiring - (fig. 12)

NB: In fig. 12 connections involving the rear panel are shown on the right-hand side of the figure.

☐ Use a piece of bare wire (1) to connect contact Z of switch SW1 with contact 1 of switch SW2. Use figs. 6 and 7 to identify the correct position of the various switch contacts.

☐ Use a piece of insulated wire (2) to connect the contact 2 of switch SW2 to terminal pin E of the PCB.

☐ Use a piece of insulated wire (3) to connect contact 3 of SW2 to the central terminal Y of potentiometer P6 (D-Q).

☐ Use a piece of bare wire (4) to connect contact 4 of SW2 with side terminal V of potentiometer P3.

☐ Use a piece of insulated wire (5) to connect contact 6 of SW2 with terminal pin F on the PCB.

☐ Use a piece of insulated wire 6 to connect contact 7 of SW2 with terminal pin L on the PCB.

☐ Use a piece of insulated wire (7) to connect contact 13 of SW2 with terminal pin Q on the PCB.

☐ Use a piece of insulated wire (8) to connect contact 14 of SW2 with central terminal T of potentiometer P5.

☐ Use a piece of insulated wire (9) to connect contact 15 of SW2 with pin R of the PCB.

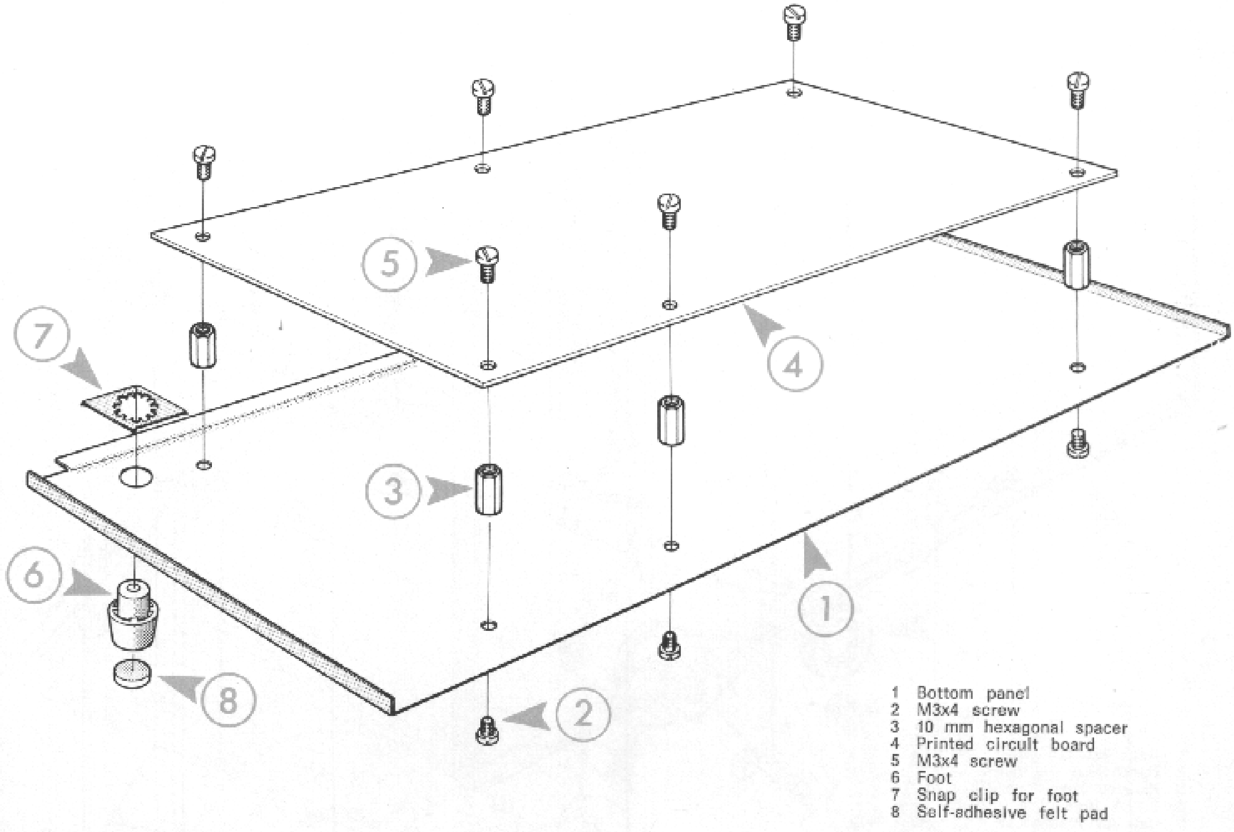


Fig. 9 - Assembling the bottom panel.

☐ Use a piece of insulated wire (10) to connect contact 16 of SW2 with terminal S of the jack socket.

☐ With a piece of bare wire (11) connect contact 9 of SW2 to terminal U of the red socket.

☐ With a piece of insulated wire (12) connect terminal U of the red socket to pin H on the PCB.

☐ With a piece of bare wire (13) connect contact «a» of switch SW1 to eyelet terminal of the black socket.

☐ Use a piece of insulated wire (14) to connect contact «a» of SW1 to pin G on the PCB.

☐ Use a piece of bare wire (15) to connect the central terminal of potentiometer P6 (D-Q) to pin M on the PCB.

☐ Use a piece of bare wire (16) to connect the lower terminal of P6 to the nearest of the pins marked ⊥ on the PCB.

☐ Use a piece of insulated wire (17) to connect the upper (SENSITIVITY) terminal of P5 to the pin marked ⊥ nearest to it on the PCB.

☐ Use a piece of insulated wire (18) to connect the central terminal T of P5 to pin N of the PCB.

☐ Use a piece of insulated wire (19) to connect the lower terminal of P5 with pin P on the PCB.

☐ With a piece of insulated wire (20) connect the positive terminal of the instrument to the pin marked + on the PCB.

☐ With a piece of insulated wire (21) connect the negative terminal of the instrument to the pin marked — on the PCB.

☐ With a piece of bare wire (22) connect together the central and upper terminals of P3 and continue the connection to the outer terminal of the jack socket.

☐ Use a piece of bare wire (23) to connect the central terminal P3 with the pin marked ⊥ nearest to it on the PCB.

☐ Connect the two insulated wires (24) and (25) from the indicator lamp to the two pins marked La on the PCB.

☐ Connect the yellow/green wire (27) of the supply cable (26) to the remaining terminal pin marked ⊥ on the PCB.

☐ Connect the brown wire (28) of the supply cable (26) to the central right-hand terminal of the mains (line) switch.

☐ Connect the blue wire (29) of the supply cable (26) to the central left-hand terminal of the mains (line) switch.

☐ Use a piece of insulated wire (30) to connect the central terminal of the voltage selector with the upper contact of the fuseholder.

☐ Use a piece of insulated wire (31) to connect the loyer contact of the fuseholder with the upper right-hand terminal of the mains (line) switch.

☐ Use a piece of insulated wire (32) to connect the upper left-hand terminal of the mains (line) switch to pin A on the PCB.

☐ Use a piece of insulated wire (33) to connect the 250 V terminal of the voltage selector to pin D of the PCB. The

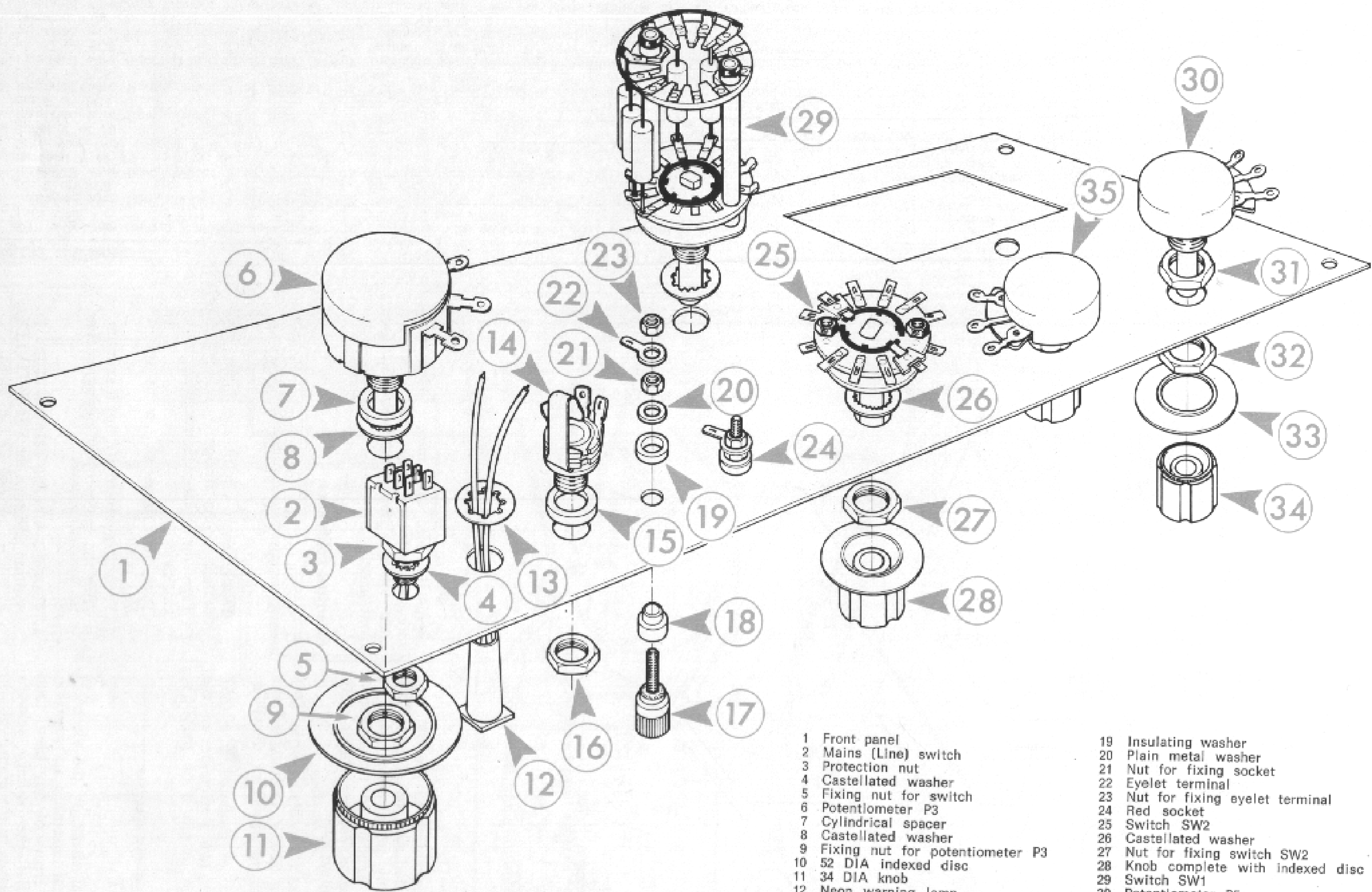
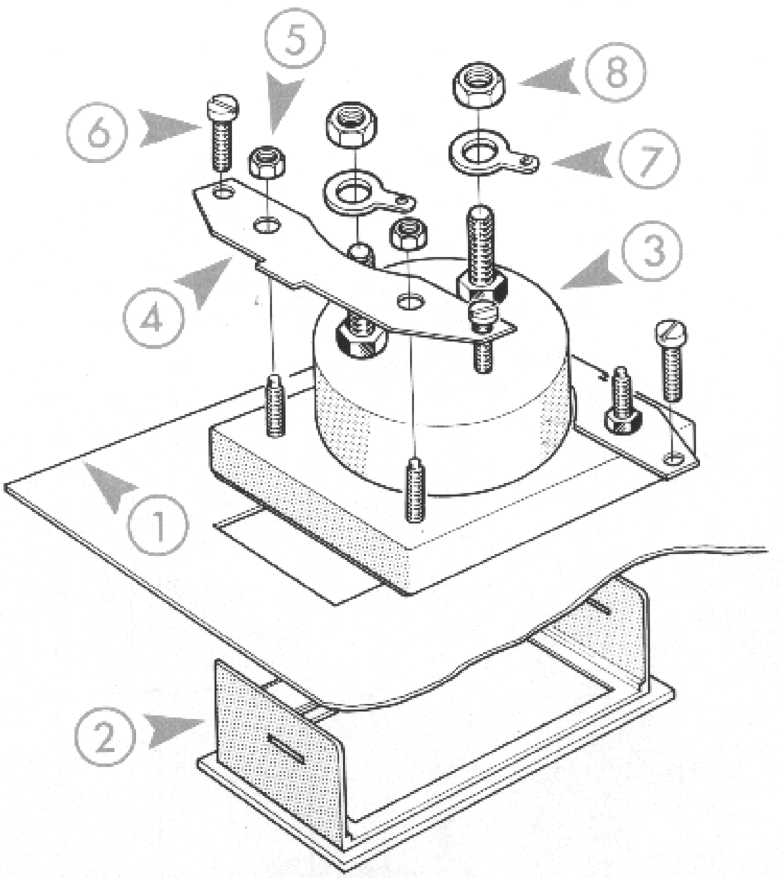


Fig. 10 - Assembling the components to the front panel.

1 Front panel
2 Mains (Line) switch
3 Protection nut
4 Castellated washer
5 Fixing nut for switch
6 Potentiometer P3
7 Cylindrical spacer
8 Castellated washer
9 Fixing nut for potentiometer P3
10 52 DIA indexed disc
11 34 DIA knob
12 Neon warning lamp
13 Snap ring for fixing lamp
14 Jack socket
15 Cylindrical spacer
16 Nut for fixing jack socket
17 Black socket
18 Insulated bush
19 Insulating washer
20 Plain metal washer
21 Nut for fixing socket
22 Eyelet terminal
23 Nut for fixing eyelet terminal
24 Red socket
25 Switch SW2
26 Castellated washer
27 Nut for fixing switch SW2
28 Knob complete with indexed disc
29 Switch SW1
30 Potentiometer P5
31 Hexagonal nut
32 Fixing nut for potentiometer P5
33 32 DIA indexed disc
34 20 DIA knob
35 Potentiometer P6



1 Front panel
2 Frame
3 Instrument
4 Tongued plate for fixing instrument to frame
5 M3 nut
6 Screw for tightening up
7 Eyelet terminal
8 Nut for fixing terminal

Fig. 11 - Mounting the instrument.

contacts corresponding to the different voltages provided by the selector can be identified by noting that when a given voltage appears in the window, the corresponding contact shorts with the central contact.

☐ Use a piece of insulated wire (34) to connect the 220 V terminal of the voltage selector to pin C of the PCB.

☐ Use a piece of insulated wire (35) to connect the 115 V terminal of the voltage selector to pin B on the PCB.

CALIBRATION OF THE INSTRUMENT

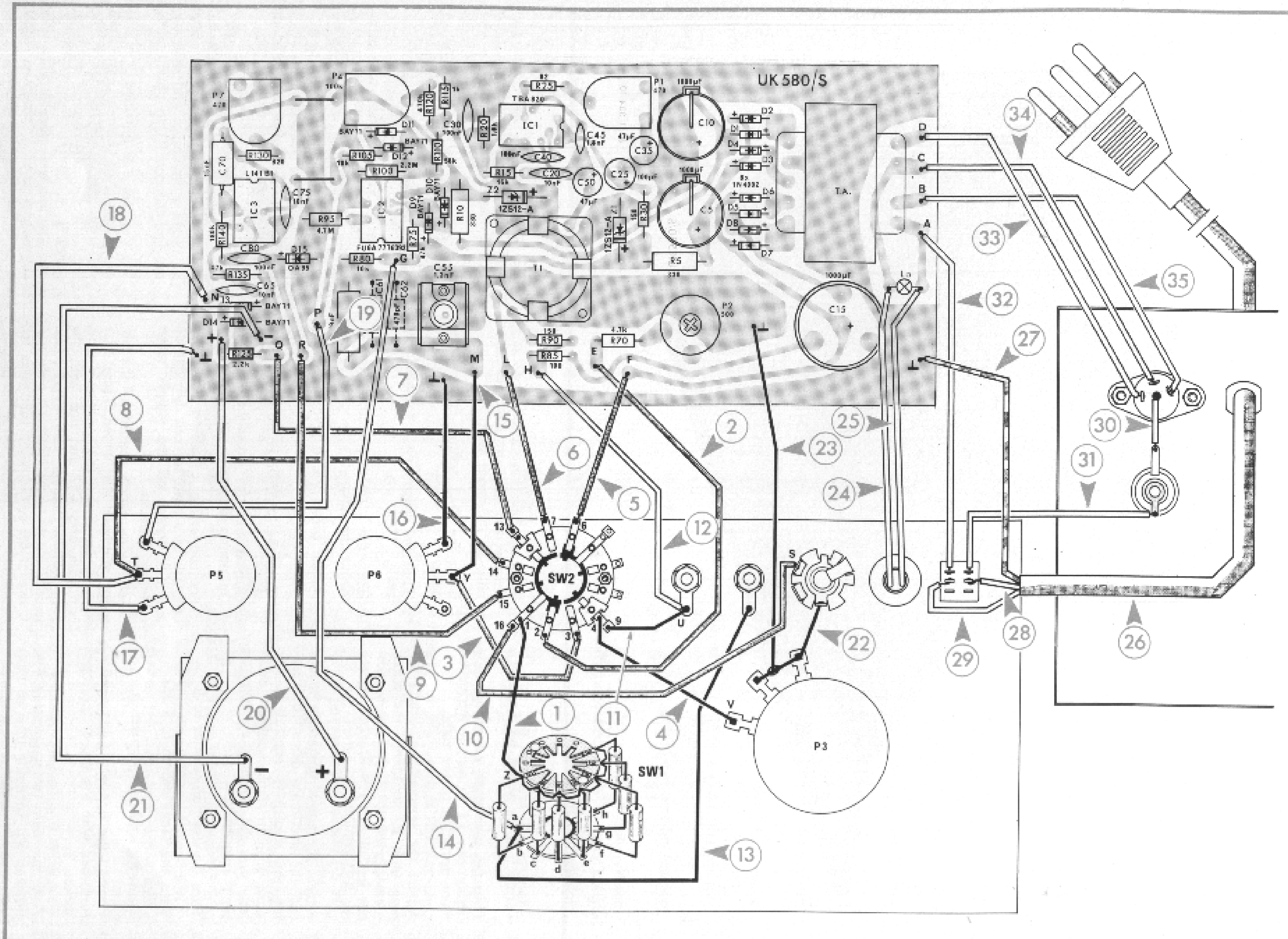
Make a final check on the electrical and mechanical assembly to see that there are no errors of any kind, then make sure that the voltage selector switch corresponds to the mains voltage. Insert the mains (line) plug and switch on the instrument; first, however, mechanically zero the meter using the screw beneath the scale, which is reached via the appropriate hole in the front panel.

Electrical calibration

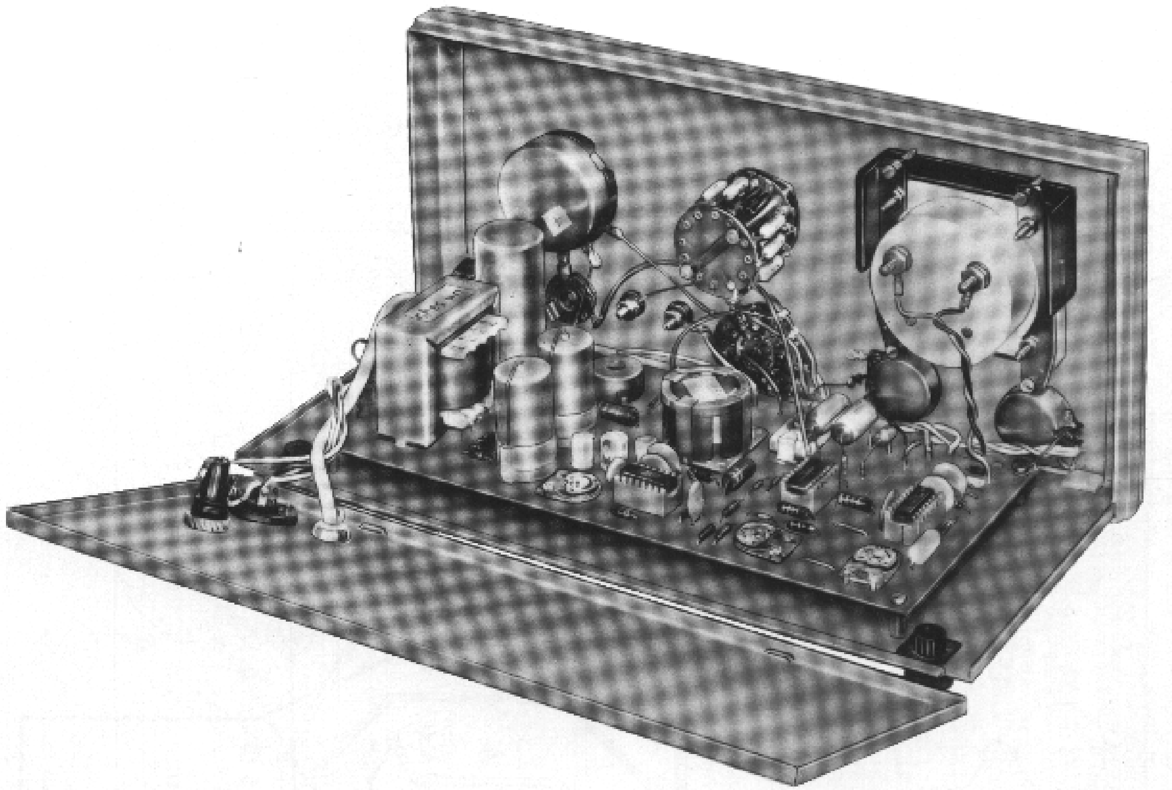
1. Switch on the instrument.
   Put the RLC switch into the R position.
   Firmly short circuit the input terminals to the bridge.
   Turn the balance knob fully anticlockwise.
   Turn the range switch to the 1 MΩ position.
   Turn the sensitivity to maximum.
   Zero the meter using potentiometer P4.
2. Turn the function selector to the C position and turn the SENSITIVITY switch up by one or two steps.
3. Turn the RANGE switch to 100 µF.

Fig. 12 - Wiring.

1. Stiff wire from contact Z of SW1 to contact 1 of SW2
2. Insulated wire from contact 2 of SW2 to pin E on PCB
3. Insulated wire from contact 3 of SW2 to terminal Y of P6
4. Stiff wire from contact 4 of SW2 to terminal V of P3
5. Insulated wire from contact 6 of SW2 to pin F on PCB
6. Insulated wire from contact 7 of SW2 to pin L on PCB
7. Insulated wire from contact 13 of SW2 to pin Q on PCB
8. Insulated wire from contact 14 of SW2 to terminal T of P5
9. Insulated wire from contact 15 of SW2 to pin R on PCB
10. Insulated wire from contact 16 of SW2 to terminal S of jack socket
11. Stiff wire from contact 9 of SW2 to terminal U of red socket
12. Insulated wire from terminal U of red socket to pin H on PCB
13. Stiff wire from contact a of SW1 to terminal of black socket
14. Insulated wire from contact a of SW1 to pin G on PCB
15. Stiff wire from terminal Y of P6 to pin M on PCB
16. Stiff wire from lower terminal of P6 to pin on PCB
17. Insulated wire from upper terminal of P5 to pin on PCB
18. Insulated wire from terminal T of P5 to pin N on PCB
19. Insulated wire from the lower terminal of P5 to pin P on PCB
20. Insulated wire from the + terminal of the instrument to the pin marked + on the PCB
21. Insulated wire from the — terminal of the instrument to the pin marked — on the PCB
22. Stiff wire joining the central and upper terminals of P3 and connecting them to the earth terminal of the jack socket
23. Stiff wire from central terminal of P3 to pin on PCB
24. Insulated wire from warning lamp to the left-hand terminal pin marked La on the PCB
25. Insulated wire from warning lamp to the right-hand terminal pin marked La on the PCB
26. Supply cable
27. Yellow/green wire of the supply cable to pin of the PCB
28. Brown wire of the supply cable to the right-hand central terminal of the mains (line) switch
29. Blue wire of the supply cable to the left-hand central terminal of the mains (line) switch
30. Insulated wire from the central contact of the voltage selector to the upper contact of the fuseholder
31. Insulated wire from the upper right-hand terminal of the mains (line) switch to the lower contact of the fuseholder
32. Insulated wire from the upper left-hand terminal of the mains (line) switch to pin A on the PCB
33. Insulated wire from the 250 V contact of the voltage selector to pin D on the PCB
34. Insulated wire from the 220 V contact of the voltage selector to pin C on the PCB
35. Insulated wire from the 115 V contact of the voltage selector to pin B on the PCB



UK 580/S
SW1
SW2
P3
P5
P6
T.A.



Internal view of the almost completed UK 580/S.

4. Turn P3 to its centre position.

5. Turn the oscillator's adjustment potentiometer P1 to obtain the maximum deviation to the right.

6. Adjust the selective amplifier's tuning with P7 to obtain the maximum deviation. If the meter exceeds its full scale deflection, reduce the SENSITIVITY control.

7. Repeat the above operations to obtain the maximum deviation, keeping the sensitivity control in the same position. This tunes the oscillator and the selective amplifier to same frequency.

8. Turn the function selector to R.

9. Turn the range switch to 1 kΩ.

10. Turn P3 knob to position 10.

11. Connect the standard 1 kΩ resistor, furnished with the kit, to the input socket.

12. Zero the meter using preset potentiometer P2. In doing this we have now calibrated the resistance scale.

13. Turn the function switch to C and connect the standard 1000 pF capacitor to the input sockets.

14. Turn the D-Q control fully clockwise.

15. Turn the range switch to the 1 nF scale.

16. Turn the knob of potentiometer to about the figure 5.

17. Adjust preset P4 to give maximum deflection on the meter.

18. Turn the knob of P3 to figure 10.

19. Adjust trimmer capacitor C55 for minimum deflection on the meter.

Try connecting capacitors C61 and C62, one at a time, to their appropriate positions **Switch off the supply when soldering them in.**

See under which conditions the absolute minimum is obtained. Three tries have to be made: one with only C61, one with only C62 and one with the two; adjust trimmer C55 every time, making a note of the minimum obtained. Leave in the combination that gives the minimum that is nearest to zero.

The instrument has now been calibrated both for the capacitance range as well as the inductance range.

HOW TO USE THE UK 580/S

Resistance measurement

1. Switch on the instrument and ensure that the SENSITIVITY control is turned to minimum (anticlockwise).

2. Turn the function selector to R.

3. Connect the unknown resistor to the terminals.

4. Increase the sensitivity to obtain a meter deflection that is about half full scale. Turn the RANGE switch to obtain a minimum and then turn the fine balance P3 to obtain zero.

5. Read the value so obtained. The scale of P3 gives the decimal part of the value on the RANGE switch. For example, if the zero occurs when the RANGE is on 10 kΩ and P3 is at 7.3 on the fine balance scale, then the value of the unknown resistor will be 10.000x 0.73 = 7,300 Ω.

Inductance measurement

1. Switch on the instrument, making sure first that the SENSITIVITY is at minimum (anticlockwise).
2. Turn the function selector to L.
3. Turn the D-Q control fully clockwise.
4. Connect the inductor to the measurement terminals.
5. Turn P3 to the figure 5.
6. Adjust the SENSITIVITY control to produce about a full scale deflection on the meter.
7. Turn the RANGE switch to obtain the minimum deflection on the meter.
8. Turn the knob of P3 for a minimum deflection on the meter; then turn the D-Q control so the meter deflects even less; again adjust P3 to reduce the reading further and so on until the minimum possible is obtained.
9. Read the value so obtained. For example, if the RANGE selector is on 10 H and potentiometer P3 points to 4.6, then our inductor's value is 10x 0.46 = 4.6 H.

If a minimum cannot be obtained, this means that the inductor is open circuit.

Capacitance measurement

1. Switch on the instrument, first ensuring that the SENSITIVITY control is turned to a minimum (anticlockwise).
2. Turn the function selector to L.
3. Turn the D-Q control fully clockwise.
4. Connect the capacitor to be measured to the terminals.
5. Turn P3 to figure 5.
6. Adjust the SENSITIVITY control so that the meter reads about full scale.
7. Turn the RANGE switch to obtain minimum deflection on them meter.
8. Turn the knob of P3 to obtain the minimum deflection; then turn the D-Q control and see that it decreases further; go back to P3 for a further minimum and so until the least reading possible is obtained. In general, when capacitors are being measured, the D-Q control has less effect than with inductors. The only exception is if the capacitor is particularly lossy.
9. Read the value obtained. For example, if the RANGE switch points to 10 nF (= 10,000 pF) and the fine balance P3 points to 8.9 then the capacitor's value will be: 10,000x 0.89 = 8,900 pF = 8.9 nF.

If the measurement cannot be successfully made, this means that the capacitors is short circuited.

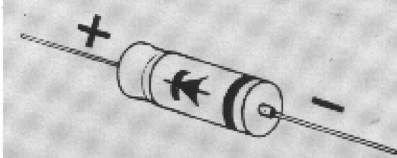
COMPONENT LIST

Qty	Code	Description
2	R30-R90	150 Ω - ± 5% - carbon film resistor 0.33 W - 2.9 DIA x 8.3
1	R85	100 Ω - ± 5% - carbon film resistor 0.33 W - 2.9 DIA x 8.3
1	R25	82 Ω - ± 5% - carbon film resistor 0.33 W - 2.9 DIA x 8.3
2	R5-R10	330 Ω - ± 5% - composition resistor 1 W - 5.7 DIA x 15
1	R130	820 Ω - ± 5% - carbon film resistor 0.33 W - 2.9 DIA x 8.3
1	R115	1 kΩ - ± 5% - carbon film resistor 0.33 W - 2.9 DIA x 8.3
1	R20	1.6 kΩ - ± 2% - carbon film resistor 0.33 W - 2.9 DIA x 8.3
1	R125	2.2 kΩ - ± 5% - carbon film resistor 0.33 W - 2.9 DIA x 8.3
1	R70	4.7 kΩ - ± 5% - carbon film resistor 0.33 W - 2.9 DIA x 8.3
2	R80-R105	10 kΩ - ± 5% - carbon film resistor 0.33 W - 2.9 DIA x 8.3
1	R15	16 kΩ - ± 2% - carbon film resistor 0.33 W - 2.9 DIA x 8.3
2	R75-R135	47 Ω - ± 5% - carbon film resistor 0.33 W - 2.9 DIA x 8.3
1	R110	56 kΩ - ± 5% - carbon film resistor 0.33 W - 2.9 DIA x 8.3
1	R140	180 kΩ - ± 5% - carbon film resistor 0.33 W - 2.9 DIA x 8.3
1	R120	470 kΩ - ± 5% - carbon film resistor 0.33 W - 2.9 DIA x 8.0
1	R100	2.2 MΩ - ± 5% - carbon film resistor 0.5 W - 4 DIA x 13.5
1	R95	4.7 MΩ - ± 5% - carbon film resistor 0.5 W - 4 DIA x 13.5
1	R35	1 Ω - ± 1% - wirewound resistor 2 W
1	R40	10 Ω - 50 ppm - 0.5% - resistor 0.5 W
1	R45	100 Ω - 50 ppm - 0.5% - resistor 0.5 W
1	R50	1 kΩ - 50 ppm - 0.5% - resistor 0.5 W
1	R55	10 kΩ - 50 ppm - 0.5% - resistor 0.5 W
1	R60	100 kΩ - 50 ppm - 0.5% - resistor 0.5 W
1	R65	1 MΩ - 50 ppm - 0.5% - resistor 0.5 W
1	—	1 kΩ - ± 1% - standard carbon film resistor , 0.33 W - 2.9 DIA x 8.3
1	P2	500 Ω wire-wound trimmer (linear) 2 W 19.6 DIA
1	P4	100 kΩ trimmer (linear) - 0.25 W 16 x 20.5 horiz. mtg.

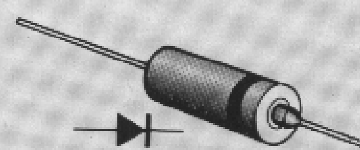
COMPONENT LIST

Qty	Code	Description
2	P1-P7	470 Ω trimmer (linear) - 0.25 W 16 x 20.5 horiz. mtg.
1	P6	100 kΩ potentiometer (log.) - 0.5 W 25 DIA
1	P5	10 kΩ potentiometer (log.) - 0.5 W 25 DIA
1	P3	5 kΩ - 5% wire-wound potentiometer (linear) 4 W
1	C45	1.8 nF - ± 10% - ceramic disc capacitor 500 V - 11 DIA x 5
3	C20-65-75	10 nF - ± 10% - ceramic disc capacitor 50 V - 13.5 DIA x 3
1	C70	15 nF - ± 10% - polyester capacitor 400 V - 7.5 DIA x 18 horiz.
3	C30-40-80	100 nF - −20+80% - ceramic disc capacitor - 25 V - 13.5 DIA x 3
1	60	19 nF - −0+5% - type 026 polystyrene capacitor - 7 DIA x 22
1	C61	1 nF - ± 5% - polystyrene capacitor 160 V - 6.2 DIA x 12 horiz.
1	C62	470 pF - ± 5% - polystyrene capacitor 160 V - 5.3 DIA x 8 horiz.
2	C35-C50	47 µF electrolytic capacitor - 16 V - 8 DIA x 12 vert.
1	C25	100 µF electrolytic capacitor - 16 V - 10 DIA x 12 vert.
2	C5-C10	1000 µF electrolytic capacitor - 25 V - 20 DIA x 34 vert.
1	C15	1000 µF electrolytic capacitor - 50 V - 26 DIA x 48 vert.
1	—	1000 pF - ± 1% - standard polystyrene capacitor type 026
1	C55	1300 pF ceramic capacitor
8	D1-2-3-4-D5-5-6-7-8	1N4002 (or 10D2) diode
6	D9-10-11-12-13-14	BAY71 (or BA128) diode
1	D15	OA95 (or AA119) diode
2	Z1-Z2	1ZS12-A (or PL12Z) zener diode
1	IC2	FU6A7776393 dual in-line integrated amplifier
1	IC3	L141B1 integrated amplifier
1	IC1	TBA20T integrated amplifier
1	T1	coupling transformer
1	S.T.	mains (line) transformer
1	—	black front panel socket
1	—	red front panel socket
1	—	red neon warning lamp 220 V 1 mA

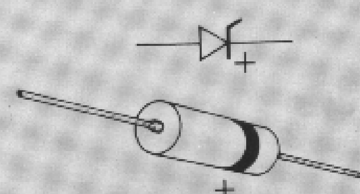
SEMICONDUCTOR TERMINAL ARRANGEMENT



1N4002 (10D2)
BAY71
(B128 - BAW75)



OA95 (AA118-AA119)



1ZS12-A
(PL12Z - BZX1C12)

COMPONENT LIST

Qty	Code	Description
5	—	14-pin IC socket
1	—	panel mounting fuseholder
1	—	0.1 A 250 V fuse 5 DIA x 20
1	—	2-pole mains (line) toggle switch 3 A 250 V
1	—	supply cable
1	—	voltage selector
1	—	50-0-50 μA indicating meter type BM55RQ
2	—	3 mm spacer for potentiometer
1	—	printed circuit board
1	—	jack socket
1	—	tilt support
1	—	front panel
1	—	frame
1	—	base
1	—	top panel
2	—	side panel
1	—	rear panel
2	—	foot
2	—	felt pad
2	—	clip
1	—	range switch 1 pole, 7 position, 1 wafer
1	—	function switch 4 pole, 3 position, 2 wafer
4	—	indexed knob 32 DIA
1	—	indexed knob 52 DIA
20 cm	—	11-strand PVC insulated wire
40 cm	—	bare tinned copper wire 1 DIA
12	—	M3x4 screw
25+2	—	PCB terminal pin
2	—	M3 nut
2	—	M3x8 screw
6	—	10 mm hexagonal spacer
4+1	—	2.9 x 6.5 self-tapping screw
4	—	2.9 x 9.5 self-tapping screw
30 cm	—	bare tinned copper wire 0.7 DIA
4	—	eyelet terminal
1	—	cable clamp
1	—	hexagonal (Allen) key
1	—	packet of solder