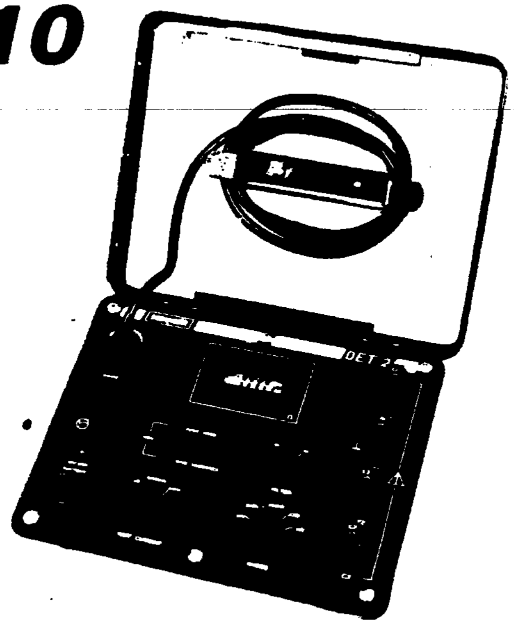
DET2 & DET2/110

MEGGER® Digital Earth Testers



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MEGGER

Operating Instructions

Safety in the Use of Electrical Equipment

It should be understood that any use of electricity inherently involves some degree of safety hazard.

Various safety regulations and recommendations are in existence and new ones are being formulated in an attempt to reduce the extent of such hazard. This is achieved principally by defining, as far as possible, the levels of voltage and current above which there is significant hazard; by establishing certain principles in the design of equipment and by recommending specific visual warnings of any residual hazard, to be placed on the equipment.

We, in common with other responsible manufacturers, take all reasonable steps to ensure that our products comply with relevant approved safety standards. However, it must be emphasised that certain types of electrical testing essentially involve the use of voltages and currents above the limits defined as 'safe' values. For example, insulation testing and flash testing generally require the use of high voltages well above the safe limit and it may not always be possible to restrict the currents available from the test equipment to within the defined safe values.

It is recommended that the user of electrical equipment of any sort should always ensure that he understands, in detail, the equipment's characteristics so that he is aware of the degree of safety hazard which may be involved.

Safety in the use of Electrical Equipment

Whilst every effort is made by responsible manufacturers to reduce the hazards and to warn of any hazard remaining, it still rests with the user to play his part in ensuring his own safety.

The best way to achieve this is:–

- **UNDERSTAND THE EQUIPMENT YOU ARE PROPOSING TO USE, AND ITS RATINGS.**
- **UNDERSTAND THE APPLICATION TO WHICH THE EQUIPMENT IS TO BE PUT.**
- **ENSURE THAT ALL REASONABLE SAFETY PROCEDURES ARE FOLLOWED.**
- **TAKE NO CHANCES, NOR SHORT-CUTS IN SAFETY PROCEDURES.**

The equipment described in this booklet has been examined, both in design and manufacture, to ensure that safety hazards are minimised.

Any known remaining hazards are explained in the paragraphs headed "Warning" on page 8 and "SAFETY PRECAUTIONS FOR ALL LIVE EARTHS" on page 10.

If, for some specific application, it is found that the information provided is not adequate, then please contact the manufacturer for further details and assistance.

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General Description

The DET2 Digital Earth Tester is a completely self-contained instrument designed to give accurate measurements of earth electrode resistance, soil resistivity etc. It uses the reversing d.c. technique.

The instrument is housed in a robust insulated portable case, which being yellow in colour is easily visible from a distance. All the controls, the terminals and the liquid crystal display digital panel meter are mounted on the panel underneath the hinged cover. The instrument is 'splash proof' and suitable for outdoor use in most weather conditions.

Power for the instrument is provided from re-chargeable cells contained within the instrument. Alternatively the power source may be an external 12V battery and the terminals for its connection are on the panel.

The Range switch selects 'OFF' or one of the four resistance ranges, 2Ω, 20Ω, 200Ω or 2000Ω and the digital panel meter indicates the measurement directly in ohms. One switch selects either 'LOW', 'NORMAL' or 'HIGH' test current and another switches 'IN' or 'OUT' the added filter circuit available. Visual indication is given, by lamps glowing, of a high current spike resistance or a high input noise level. Also when the batteries are on charge a neon lamp illuminates, to show that a mains supply is connected. The lead fitted through the panel and stored in the hinged cover is for connection to a mains supply for battery charging. This should be 200V-240V, 50 or 60Hz for the DET2 and 100V-120V, 50 or 60Hz for the DET2/110.

Applications

The installation of satisfactory earthing systems and their maintenance has become an essential part of electrical supply, wiring safety and installations economics.

In order that an earth electrode may perform satisfactorily it is necessary that it should have a low total resistance. The value will be influenced by the specific resistance of the surrounding soil. This in turn depends on the nature of the soil and its moisture content. Before sinking an electrode, therefore, it is often advantageous to survey the surrounding sites before choosing the final site for the electrode. It is possible with this instrument to measure from the surface the resistivity of the soil at different levels beneath the ground. This may indicate the advisability of driving electrodes to a greater depth, rather than increasing costs by having to add further electrodes and associated cables, in order to reach a specified total earth system resistance.

After installation, checks may be made of each element of an earth system which will yield information on the resistance under different soil moisture conditions. Also such checks will indicate whether there is a need for the maintenance of the installation, if the required resistance to earth has been exceeded.

The instrument may be used also for checking the 'touch potential' and 'step potential' relating to earthing systems.

For archaeological and geological purposes, an investigation of soil structure and building remains can be carried out at varying measured depths.

Detailed methods of obtaining soil resistivity readings are given in later pages. In every case the accuracy of the instrument readings may be taken to be higher than the natural variables in soil characteristics.

A further application of the instrument is continuity testing e.g. checking the resistance of conduit used as an earth path.

Specification

Earth Resistance Ranges	0,001 – 1,999Ω 0,01 – 19,99Ω 0,1 – 199,9Ω 1 – 1999Ω
Accuracy (20°C)	±2% of reading ±2 digits.
Temperature Effect	±0,1% per °C.
Working Temperature Range	-15°C to +50°C.
Storage Temperature Range	−30°C to +70°C
Humidity	95% R.H. combined with cyclic temperature changes of 25°C to 40°C (BS2011: Part 2.1, Db: 1977, IEC 68-2-30: Test Db: 1969)
Test Frequency	128Hz reversing d.c.
Interference	Steady interference voltages at d.c., 50 or 60Hz will be rejected. The effect of transient noise is minimised by a switched filter. Maximum interference:— 2Ω range low current ± 5V peak 2Ω range normal current ± 10V peak all other ranges and currents ± 20V peak
Filter Time Constant	Normal (filter switch 'OUT') 1 second. Long (filter switch 'IN') 10 seconds.
Test Current	High 40mA Normal 10mA Low 5mA
Maximum Current Spike Resistance	The maximum permissible resistance of the current loop depends on the test current selected:- High current 800Ω Normal current 3,5kΩ Low current 7,5kΩ

Maximum Potential Spike Resistance	The input impedance between the potential terminals is 2MΩ. A maximum potential loop resistance of 10kΩ will give an additional error of 0,5%.
Output Voltage	50V maximum from the C1,C2 terminals.
Display	3½ digit l.c.d. maximum reading 1999.
Power Supply	Internal, rechargeable Ni Cd cells. Battery life:— 6 hours minimum continuous on 'NORMAL' or 'LOW' test current. 2 hours minimum continuous on 'HIGH' test current. Battery charging supply:— 200V—240V, 50 or 60Hz for the DET2 and 100V—120V, 50 or 60Hz for the DET2/110. Battery charging time:— 12 hours for full charge. Alternative power supply:— external 12V source, e.g. car battery.
Fuses	Battery fuse:— 3,15A (T) 20x5mm glass (slow blow) Mains supply:— DET2 — 100mA 20x5mm ceramic. DET2/110—250mA 20x5mm glass.
Safety Class	Class I when cells are being charged. Class III when operated. (IEC 348 2nd. Edition 1978).
Dimensions	260 x 225 x 220mm approx. (10¼ x 8⅞ x 8⅝ in. approx).
Weight	3,5kg (7,7lb)

Instrument Operation

GENERAL

Warning: As a precaution when working near high tension systems where accidental high potentials on the structure and in the ground are possible, it is recommended that the operator wears rubber gloves, and stands on a rubber mat or wears rubber shoes.

1. The digital panel meter reveals the state of the battery because, with the instrument switched on the display will not illuminate if the cells are not charged. If the battery condition is satisfactory, with nothing connected to the terminals, the display digits will illuminate with random numbers and all the decimal points will be visible. Also the high spike resistance l.e.d. will light up.

   It is advisable that the cells be charged fully before going out into the field to make tests (i.e. charge over-night). This is because the battery can change from an usable state to a non-usable state in a very short space of time, which would be inconvenient if it occurred while field tests were in progress.

   TO CHARGE THE BATTERY connect the flying lead stored in the instrument lid, to a suitable mains supply (see specification page 6). The mains neon will illuminate while the battery is being charged.

   The instrument MUST NOT be used whilst connected to a mains supply.

2. For earth testing, the leads are connected from spikes hammered into the ground, to the instrument terminals, (refer to Measuring Techniques page 12). The instrument may be used out of doors in almost any weather conditions.

3. Switch the instrument on and select the correct range by rotating the RANGE switch and reading the measurement in ohms from the digital panel meter display. Over-range is indicated by a 1 as the left hand digit with the remainder blank. Always use the most sensitive range possible.

4. If the input noise level is too high, indication is given by the 'INPUT NOISE' lamp (and all the decimal points in the digital display) illuminating. The TEST CURRENT must then be increased.

   If the current loop (spike) resistance is too high indication is given by the 'SPIKE RESISTANCE' lamp (and all the decimal points in the digital display) illuminating. The TEST CURRENT must then be reduced.

5. If either the 'INPUT NOISE' lamp or the 'TEST CURRENT' lamp illuminates (and also the decimal points in the digital display), ***on all test currents,*** this means that the test cannot be made with the test spikes (electrodes) in that condition. The spike resistance can be improved, either by moistening the ground into which they are hammered or else re-positioning them; alternatively larger spikes can be used or more than one spike used at the same distance. Input noise may be reduced by re-positioning the test spikes and test leads avoiding possible causes of interference. For the majority of readings the TEST CURRENT switch should be in the 'NORMAL' position.

6. If there is a lot of "flicker" on the digital panel meter display whilst a measurement is being taken, the FILTER switch may be turned to the 'IN' position. This increases the amount of filtering and the reading should be taken after one minute to allow the filter to obtain its steady state value. The reading will then be more stable.

7. If the rechargeable batteries are exhausted, the instrument may be supplied from a 12V external battery, e.g. a car battery. Connect the battery to the 12V EXT. BATTERY + and – terminals on the left-hand side of the front panel. Take care to observe the correct polarity.

8. Turn the RANGE switch to 'OFF' when measurements are not being made.

CHANGING FUSES AND BATTERY REPLACEMENT

1. **Changing Fuses**

   Two fuses, a mains supply fuse and a battery fuse, are located within the instrument. Access to them is obtained by removing the instrument from the case. With the instrument disconnected from the mains supply, the mains cable unwound from its holder, the terminals disconnected and the range switch set to 'OFF', release the six fixing screws securing the instrument into the case, and remove them. Lift the instrument out of the case carefully and lay it face downwards on a clean bench.

   The mains supply fuse (DET2 – 100mA 20x5mm ceramic, DET2/110 — 250mA 20x5mm glass) is held in a fuse clip and located on the main p.c.b. next to the mains supply transformer.

   The battery fuse (3,15A(T) 20x5mm glass) is located on the chassis, adjacent to a relay and near the external battery terminals.

   Replace the instrument carefully into the case after the necessary fuse change has been made. Ensure that the sealing gasket is fitting correctly around the panel edge, then replace the screws and tighten them down.

   Note:– If a fuse ruptures, it is indicative of a fault in the instrument circuit which requires investigation.

2. **Battery Replacement**

   The rechargeable batteries are located within the instrument; access to them is obtained in the same way as described above for replacing the fuses. However, the working life of a rechargeable battery is expected to be many years, and when it needs replacing the instrument should be returned to the manufacturer or a distributor.

Instrument Operation

SAFETY PRECAUTIONS FOR ALL LIVE EARTHS

Safety precausions are necessary when any live earths may be encountered e.g. when testing the earth of a live sub-station. If a fault occurs at the substation while a test is being conducted, dangerous voltages may exist between the site earth and remote earths established for test purposes.

1. The instrument must be used within the perimeter fence of the substation where the test is being conducted, and/or in an area where the voltage difference from the earth under test does not exceed 50V in any circumstances. If this is not possible then rubber gloves and mats must be used.

2. The P1 and C1 terminals must be connected to the earth electrode being tested.

3. The P2 and C2 terminals must be connected to an isolation switch, whose rating will cope with the maximum fault voltages (refer to fig. 1).

4. With the isolation switch open, connections to the remote electrodes may be established. Make the connections to the isolation switch first and then connect the remote electrodes.

5. When the remote electrodes have been established the isolation switch may be closed and a test made.

6. Whilst the test is in progress care must be taken that no one comes into contact with the remote electrodes or the wires running to the P2 and C2 terminals via the isolation switch.

The isolation switch must be open whilst contact is made with the remote earths or the connecting wires, e.g. when changing their positions.

If a fault occurs while a test is being made the instrument may be damaged. Fusing of the remote electrodes at the isolation switch with 100mA fuses, of suitable rating to cope with the maximum fault voltage, will provide protection for the instrument (see fig. 1).

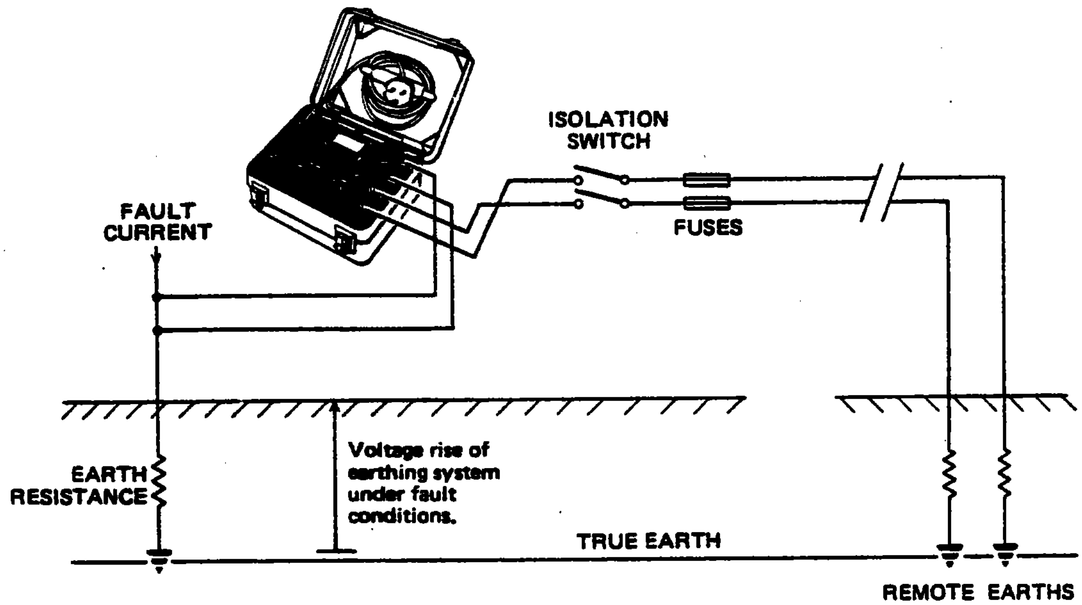


Figure 1 A method of connection where fault conditions may occur

1. **NORMAL METHOD OF TEST FOR SMALL EARTHING ELECTRODES** (see fig. 2)
(employing the fall of potential method)
The terminals C1 and P1 are connected to the earth electrode being tested. A test spike is hammered into the ground 30m to 50m away and is connected to the C2 terminal. This is the remote current electrode. Another test spike is hammered into the ground mid-way between the remote current electrode and the earth electrode under test and in line with them, and is connected to the P2 terminal. This is the remote potential electrode. When running wires out to remote electrodes it is preferable not to lay them close to each other in order to minimize the effect of mutual inductance.

The earth electrode resistance is measured as described in 'Instrument Operation' on page 8.

Two more tests are made with the remote potential electrode at distances 3m either side of the mid-way position. If the resistance readings agree with each other within the required accuracy, the mean value is used. If the readings disagree beyond the required accuracy then the method using the 61,8% rule must be employed.

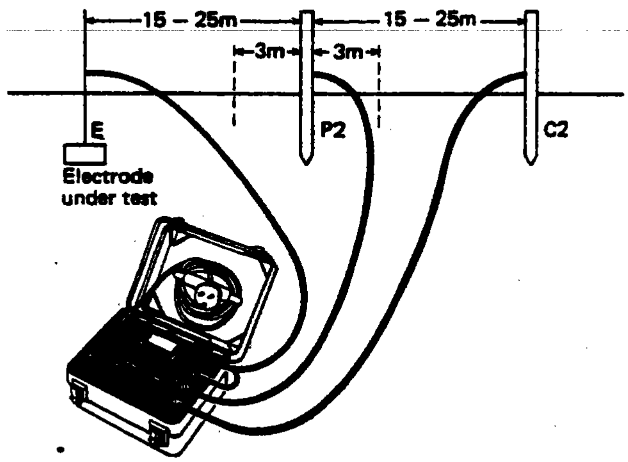


Figure 2 Resistance to earth of an earth electrode

2. THE 61,8% RULE FOR SINGLE EARTH SYSTEMS

(medium size earthing systems)
If the method of test given above yields unsatisfactory results, this method of test must be used.
To obtain a sensible reading, the remote current electrode must be correctly sited in relation to the earth electrode being tested. Since both possess 'resistance areas', the former must be sufficiently remote to prevent these areas from overlapping (see fig 3). Furthermore, the remote potential electrode must lie between these two areas. Theoretically both the current and potential electrodes should be at an infinite distance from the earth electrode. In practice, the dimensions of the resistance areas of E and C are unknown and to allow a sufficient margin, the distance EC may be impractically high. However, the 'true' resistance of the earth electrode is obtained when the measurement is taken with the potential electrode 61,8% of the distance between the earth electrode and the current electrode, away from the earth electrode. This rule applies when all electrodes are in a straight line, the soil is homogeneous and the earth electrode covers a small area and can be approximated to a hemispherical electrode, e.g. a single rod, plate, etc.

Test Electrode Spacing

For most purposes the current electrode connected to C2 should be 30 to 50 metres from the centre of the earth electrode under test. The potential electrode, connected to P2 should be inserted in the ground 61,8% of this distance between, and in a straight line with, the other two electrodes. If the earth electrode system is large, containing several rods, these distances must be increased. For ease of use in the field the following table gives a range of distances which follows

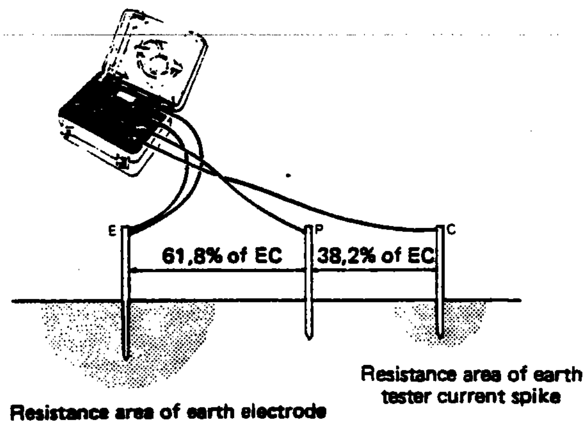


Figure 3 Connections for the 61,8% rule

this rule. In the first column "Maximum Dimension" is defined as the maximum distance across the earth electrode system to be measured.

Maximum dimension in metres	Distance to potential electrode in metres from centre of earth system	Distance to current electrode in metres from centre of earth system
5	62	100
10	93	150
20	124	200

For greater accuracy the current electrode (connected to C2) should be moved say 10m towards and away from the earth electrode system and the potential electrode should be moved in accordance with the 61,8% rule. Further measurements are made. The average of the three readings is then calculated.

3. **THE SLOPE METHOD OF TEST**
(for large earthing systems, i.e. substations, main stations or large factory sites)

(This is a summary of the slope method established and described by Dr. Tagg in his paper 6297S dated 24th August 1970. The paper was published in IEE Proceedings Vol. 117 No. 11 November 1970. Copies may be obtained from the IEE).

This technique should be used when testing earth electrode systems which cover a large area. The method is useful when the position of the centre of the earthing system is either unknown or inaccessible (e.g. if the system is beneath the floor of a building). The method yields results of greater accuracy than those detailed above.

(a) The terminals C1 and P1 on the instrument are connected to the earth electrode (see fig. 4)

(b) Connect terminal C2 to a current electrode inserted in the ground 50m or more away. The distance from the earth electrode to the current electrode is EC.

(c) The potential electrode, connected to terminal P2, is inserted at several positions between the earth and current electrodes, starting from near the earth electrode. (The electrodes must be in a straight line.) At each position the resistance is measured, and the earth resistance curve plotted from the results e.g., (see opposite), at least 6 readings are needed. Drawing the curve will show up any incorrect points which may be either rechecked or ignored.

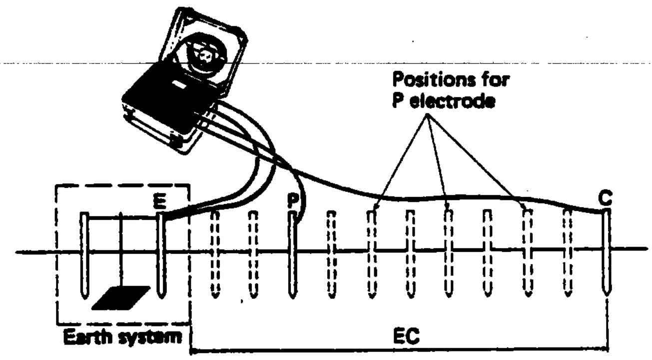
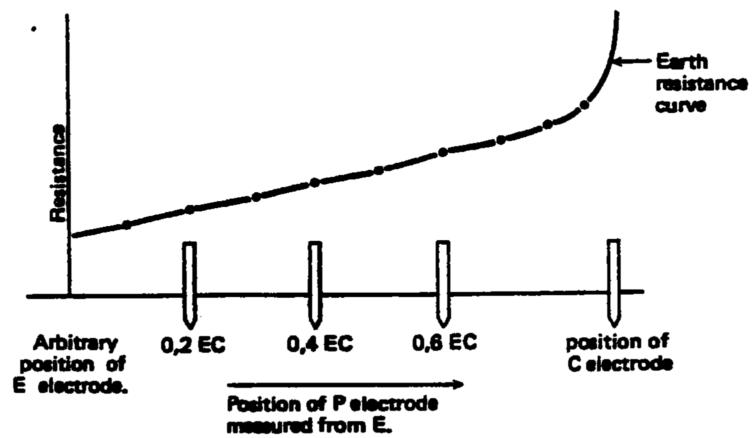


Figure 4 Instrument connection for slope method



(d) From the curve the equivalent resistance readings to potential electrode positions 0,2EC, 0,4EC and 0,6EC can be found. These become R1, R2 and R3 respectively.

(e) Calculate the slope coefficient μ

where $$\mu = \frac{R3-R2}{R2-R1}$$

which is a measure of the change of slope of the earth resistance curve.

From the table shown on page 24 obtain the value of

$$\frac{P_T}{EC}$$

for this value of μ.

P_T is the distance to the potential electrode at the position where the true resistance would be measured.

Multiply the value of $\frac{P_T}{EC}$ by EC to obtain the distance P_T

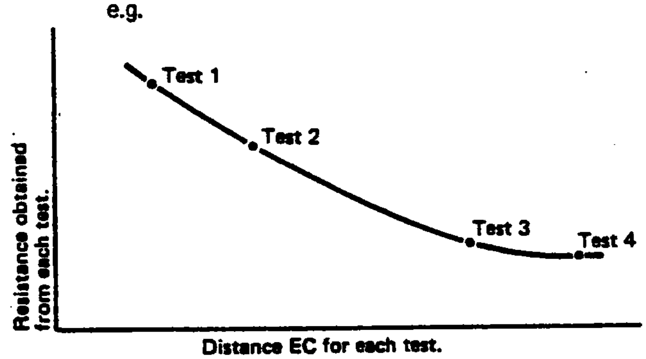
From the curve again read off the value of resistance that corresponds to this value of P_T. The value obtained is the earth system resistance.

Notes

(i) If the value of μ obtained is not covered in the table (on page 24) then the current electrode will have to be moved further away from the earthing system.

(ii) If it is required, further sets of test results can be obtained with different values of EC, or different directions of the line of EC.

From the results obtained of resistance for various values of the distance EC a curve may be plotted e.g.



This shows how the resistance is decreasing asymptotically as the distance chosen for EC is increased.

The curve indicates that the distances chosen for EC in tests (1) and (2) were not large enough; and that those chosen in tests (3) and (4) were preferable because they would give the more correct value of the earth resistance.

(iii) It is unreasonable to expect an accuracy of readings of more than 5%. 10% is often adequate bearing in mind that this sort of variation could easily occur with varying soil moisture conditions or non-homogeneous soils.

4. **ALTERNATIVE METHOD WHEN "DEAD" EARTH IS AVAILABLE**

In congested areas it may not be possible to find suitable sites for the testing spikes, nor to run the required test leads. In these cases an alternative low resistance earth such as a water main is often available. It must be of very low resistance to earth. A water main etc. must not be used if there is any chance of a live earth being experienced. The connections are as shown in fig. 5. The resistance areas of the earth under test and the "dead" earth must not significantly overlap. The earth under test and the "dead" earth must not be bonded together.

This test will give the combined resistance of the two earths in series. If that of the "dead" earth is negligible then the reading may be taken as that of the earth electrode under test. However, care must be taken in using this method since non-metallic piping and jointing is commonly found in water main installations.

The results obtained by this method are not as accurate as the two-spike systems, detailed above, which should be used as the standard practice wherever possible. Readings are affected particularly if the distance between the two earths is not large enough; this causes serious distortions in the current flow.

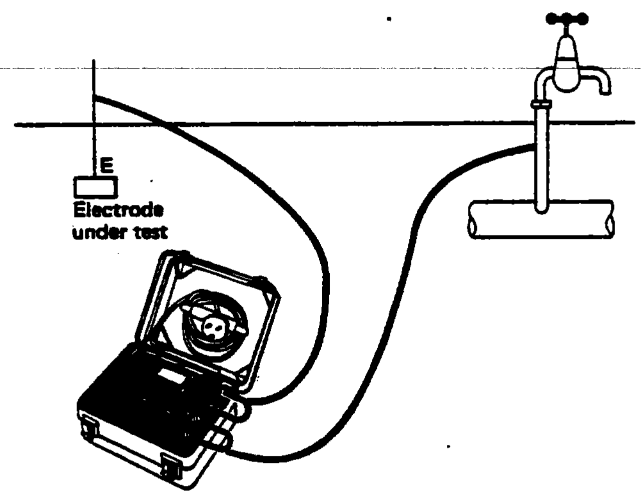


Figure 5 Connection to a water main

Measuring Techniques Determining 'Touch' and 'Step' Potential

1. **TOUCH POTENTIAL**
   Touch potential is the potential difference a person would experience across his body if he were, for example, standing on the ground outside the earthed perimeter fence of a substation and touching the fence at the time a fault to earth occurred at the substation.

(a) Connect the instrument in the following way:—
(see fig 6)
Terminal C1 to the substation earth E.
Terminal C2 to a remote current electrode C set up some distance away by a test spike inserted in the ground
Terminal P1 to the structure being tested e.g. perimeter fence.
Terminal P2 to a potential electrode P e.g. a test spike inserted into the ground 1 metre away from the perimeter fence adjacent to the point of test (where a person might stand).

(b) Operate the instrument and record the resistance indicated. This is the effective resistance between the point of test on the fence and the potential electrode as seen by the test current.

(c) The maximum value of the current that would flow in the earth when a fault to earth occurred at the substation must be known. From Ohm's law $V = I \times R$, the touch potential can be calculated.

2. **STEP POTENTIAL**
   Step potential is the potential difference a person would experience between his feet as he walked across the ground in which a fault current existed.

(a) Connect the terminals C1 and C2 as described for touch potential above.
Connect terminals P1 and P2 to potential electrodes (test spikes inserted in the ground) at positions A and B respectively (A nearest to E, see fig. 6). Positions A and B are 1 metre apart, or the length of a step.

(b) Operate the instrument and record the resistance indicated. This is the effective resistance across positions A and B, as seen by the test current.

(c) The maximum value of the current that would flow in the earth when a fault to earth occurred at the substation must be known.

From Ohm's law $V = I \times R$, the step voltage can be calculated.

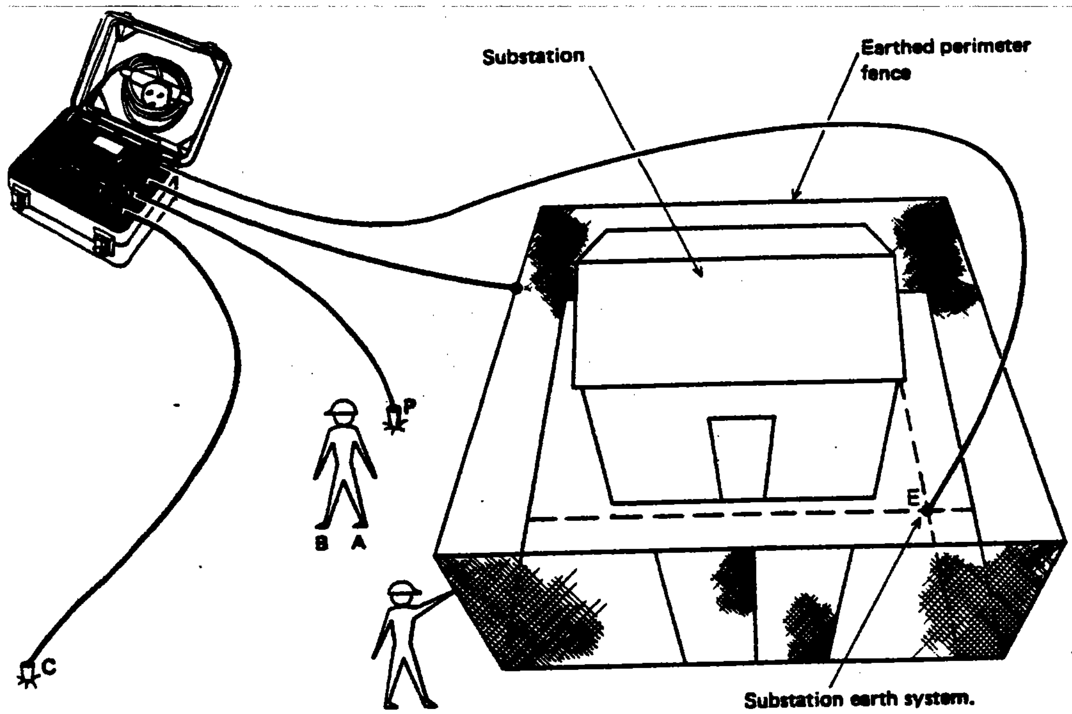


Figure 6 Method of use for determining touch potential and step potential

1. **TYPICAL VARIATIONS IN SOIL RESISTIVITY**

The resistance to earth of an earth electrode is influenced by the resistivity of the surrounding soil. The resistivity depends upon the nature of the soil and its moisture content and can vary enormously as seen in the table below:—

Material	Specific resistance in ohms-cms	Source of information
Ashes	350	Higgs
Coke	20-800	–
Peat	4,500-20,000	–
Garden earth—50% moisture	1,400	Ruppel
" " —20% moisture	4,800	"
Clay soil—40% moisture	770	"
" " —20% moisture	3,300	–
London clay	400-2,000	–
Very dry clay	5,000-15,000	–
Sand—90% moisture	13,000	Ruppel
" —normal moisture	300,000-800,000	–
Chalk	5,000-15,000	–
Consolidated sedimentary rocks	1,000-50,000	Broughton Edge & Laby

Because it is impossible to forecast the resistivity of the soil with any degree of accuracy it is important to measure the resistance of an earth electrode when it is first laid down and thereafter at periodic intervals. Before sinking an electrode into the ground for a new installation it is often advantageous to make a preliminary survey of the soil resistivity of the surrounding site. This will enable decisions to be made on the best position for the electrode(s) and to decide whether any advantage is to be gained by driving rods to a greater depth. Such a survey may produce considerable savings in electrode and installation costs necessary to achieve a required resistance.

2. **INSERTING TEST ELECTRODES**

The four test spikes are driven into the ground, in a straight line at equal distances 'a', and inserted to a depth of not more than $\frac{1}{20}$ of 'a'.

The instrument is connected to the test spikes as shown in fig. 7.

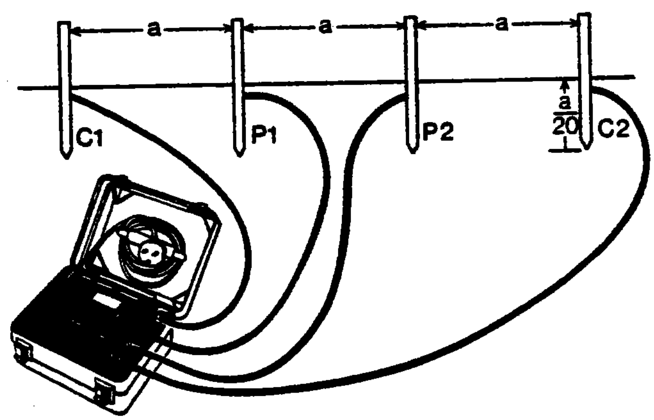


Figure 7 Connections for resistivity tests

The measurement is made in the normal way. The resistivity may be calculated from the formula given below or from the nomogram shown on page 21. This is the average soil resistivity to a depth 'a'.

The four test spikes are re-positioned for further tests. If the spacing 'a' is maintained (and the depth of insertion $\frac{1}{20}$ 'a'), a directly comparative reading will be obtained each time, and thus areas of lowest resistivity located (at constant depth 'a').

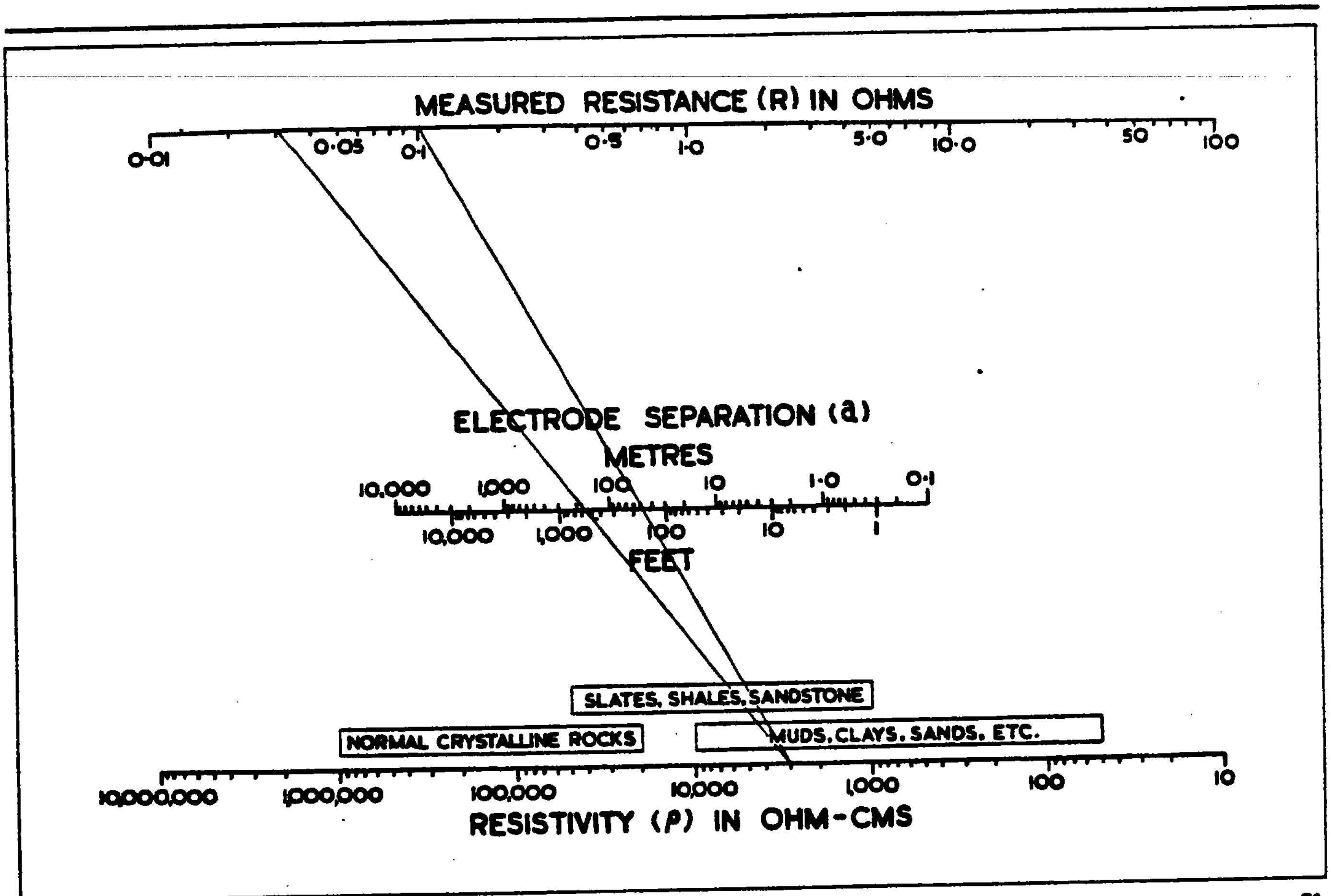
Respacing test spikes at 'b', 'c', 'd', etc. will yield results from which a profile of the readings 'b', 'c', 'd', etc. can be obtained.

3. **CALCULATION OF RESISTIVITY**
Assuming the soil to be homogeneous the resistivity is given by the formula:

$$\rho = 2\pi aR$$

where R is the resistance measured in ohms, a is the electrode spacing in metres and ρ is the resistivity in ohm-metres.

For non-homogeneous ground the formula will give an apparent resistivity which is very approximately the average value to a depth equal to the electrode spacing 'a'.



Nomogram for resistivity calculations

Measuring Techniques Continuity Testing

To test the continuity of conduit or other earth conductors the instrument is connected as shown in fig. 8. It will measure metallic resistances of low inductance or capacitance. Make sure that the circuit to be tested is 'dead' before connecting the instrument for measurement.

Due to the inherently high accuracy of the instrument and the very low continuity resistance to be measured, the contact resistance between leads and conduit, etc., becomes an increasing factor in measurement and should be as low as possible.

The resistance of the test leads may be found by connecting them to the P1 and P2 terminals and joining their free ends together.

C1-P1 and C2-P2 are connected. The measurement is made and the result subtracted from the original reading to give the value of the continuity resistance.

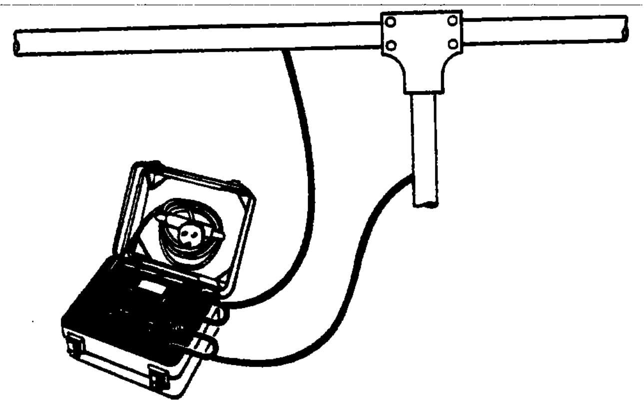


Figure 8 Continuity testing

Circuit Description (see fig. 9)

An oscillator is used to produce a basic square wave signal, divisions of which are used in various parts of the instrument. This basic square wave signal passes to a frequency divider and waveform generating circuit. The purpose of this circuit is to provide the test signal at 128Hz, and also reference signal waveforms for the phase sensitive filter and phase sensitive detector networks.

The test signal controls a constant current a.c. source powered from a 'floating' supply and switched to provide the LOW, NORMAL and HIGH test currents. The test current is passed via terminals C1 and C2 through the earth under test.

The instrument employs the 4 terminal measurement principle, and so the potential drop across the earth resistance under test is fed to the measuring circuit via terminals P1 and P2. This measurement signal passes through a test current attenuator to be reduced in accordance with the test current selected. An input buffer stage follows which prevents the measuring circuit from loading the earth resistance being tested. After this the signal passes through a range attenuator to be modified in accordance with the display range required.

To remove noise signals imposed on the test signal as it passes through the earth under test, a phase sensitive filter is employed whose reference signal is derived as described above. A phase sensitive detector whose reference signal is also derived from the same source provides a suitable d.c. signal for the display.

Extra filtering of the d.c. signal is provided by switching in a low pass filter if required. The measurement signal is then displayed on the digital panel meter calibrated to read directly in ohms.

Caution:— the instrument contains static sensitive devices.

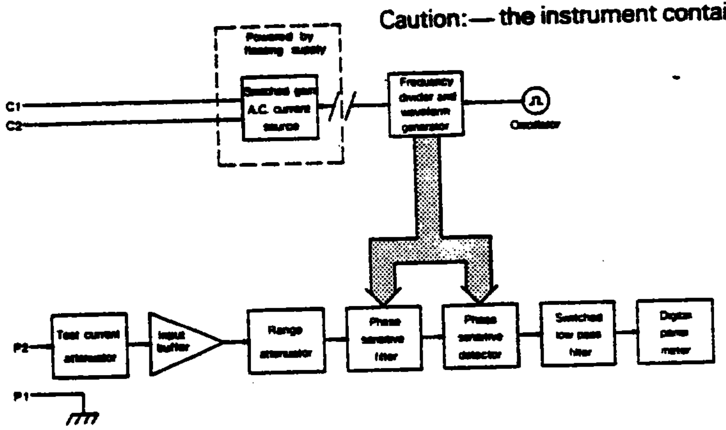


Figure 9 Block diagram

Chart for use with Slope Method

VALUES OF P_T/EC FOR VALUES OF μ

μ	0	1	2	3	4	5	6	7	8	9
0.40	0.6432	6431	6429	6428	6426	6425	6423	6422	6420	6419
0.41	0.6418	6416	6415	6413	6412	6410	6409	6408	6406	6405
0.42	0.6403	6402	6400	6399	6397	6396	6395	6393	6392	6390
0.43	0.6389	6387	6386	6384	6383	6382	6380	6379	6377	6376
0.44	0.6374	6373	6372	6370	6369	6367	6366	6364	6363	6361
0.45	0.6360	6359	6357	6356	6354	6353	6351	6350	6348	6347
0.46	0.6346	6344	6343	6341	6340	6338	6337	6336	6334	6333
0.47	0.6331	6330	6328	6327	6325	6324	6323	6321	6320	6318
0.48	0.6317	6315	6314	6312	6311	6310	6308	6307	6305	6304
0.49	0.6302	6301	6300	6298	6297	6295	6294	6292	6291	6289
0.50	0.6288	6286	6285	6283	6282	6280	6279	6277	6276	6274
0.51	0.6273	6271	6270	6268	6267	6265	6264	6262	6261	6259
0.52	0.6258	6256	6255	6253	6252	6252	6248	6247	6245	6244
0.53	0.6242	6241	6239	6238	6236	6235	6233	6232	6230	6229
0.54	0.6227	6226	6224	6223	6221	6220	6218	6217	6215	6214
0.55	0.6212	6210	6209	6207	6206	6204	6203	6201	6200	6198
0.56	0.6197	6195	6194	6192	6191	6189	6188	6186	6185	6183
0.57	0.6182	6180	6179	6177	6176	6174	6172	6171	6169	6168
0.58	0.6166	6165	6163	6162	6160	6159	6157	6156	6154	6153
0.59	0.6151	6150	6148	6147	6145	6144	6142	6141	6139	6138
0.60	0.6136	6134	6133	6131	6130	6128	6126	6125	6123	6121
0.61	0.6120	6118	6117	6115	6113	6112	6110	6108	6107	6105
0.62	0.6104	6102	6100	6099	6097	6096	6094	6092	6091	6089
0.63	0.6087	6086	6084	6083	6081	6079	6076	6076	6074	6073
0.64	0.6071	6070	6068	6066	6065	6063	6061	6060	6058	6057
0.65	0.6055	6053	6052	6050	6049	6047	6045	6044	6042	6040
0.66	0.6039	6037	6036	6034	6032	6031	6029	6027	6026	6024
0.67	0.6023	6021	6019	6018	6016	6015	6013	6011	6010	6008
0.68	0.6006	6005	6003	6002	6000	5998	5997	5995	5993	5992
0.69	0.5990	5989	5987	5985	5984	5982	5980	5979	5977	5976

μ	0	1	2	3	4	5	6	7	8	9
0.70	0.5974	5973	5971	5969	5967	5965	5964	5962	5960	5959
0.71	0.5957	5955	5953	5952	5950	5948	5947	5945	5943	5942
0.72	0.5940	5938	5936	5935	5933	5931	5930	5928	5926	5924
0.73	0.5923	5921	5920	5918	5916	5914	5912	5911	5909	5907
0.74	0.5906	5904	5902	5900	5899	5897	5895	5894	5892	5890
0.75	0.5889	5887	5885	5883	5882	5880	5878	5877	5875	5873
0.76	0.5871	5870	5868	5866	5865	5863	5861	5859	5858	5856
0.77	0.5854	5853	5851	5849	5847	5846	5844	5842	5841	5839
0.78	0.5837	5835	5834	5832	5830	5829	5827	5825	5824	5822
0.79	0.5820	5818	5817	5815	5813	5812	5810	5808	5806	5805
0.80	0.5803	5801	5799	5797	5796	5794	5792	5790	5788	5786
0.81	0.5785	5783	5781	5779	5777	5775	5773	5772	5770	5768
0.82	0.5766	5764	5762	5760	5759	5757	5755	5753	5751	5749
0.83	0.5748	5746	5744	5742	5740	5738	5736	5735	5733	5731
0.84	0.5729	5727	5725	5723	5722	5720	5718	5716	5714	5712
0.85	0.5711	5709	5707	5705	5703	5701	5699	5698	5696	5694
0.86	0.5692	5690	5688	5686	5685	5683	5681	5679	5677	5675
0.87	0.5674	5672	5670	5668	5666	5664	5662	5661	5659	5657
0.88	0.5655	5653	5651	5650	5648	5646	5644	5642	5640	5638
0.89	0.5637	5635	5633	5631	5629	5627	5625	5624	5622	5620
0.90	0.5618	5616	5614	5612	5610	5608	5606	5604	5602	5600
0.91	0.5598	5596	5594	5592	5590	5588	5586	5584	5582	5580
0.92	0.5578	5576	5574	5572	5570	5568	5565	5563	5561	5559
0.93	0.5557	5555	5553	5551	5549	5547	5545	5543	5541	5539
0.94	0.5537	5535	5533	5531	5529	5527	5525	5523	5521	5519
0.95	0.5517	5515	5513	5511	5509	5507	5505	5503	5501	5499
0.96	0.5497	5495	5493	5491	5489	5487	5485	5483	5481	5479
0.97	0.5477	5475	5473	5471	5469	5467	5464	5462	5460	5458
0.98	0.5456	5454	5452	5450	5448	5446	5444	5442	5440	5438
0.99	0.5436	5434	5432	5430	5428	5426	5424	5422	5420	5418

Chart for use with Slope Method

μ	0	1	2	3	4	5	6	7	8	9
1.00	0.5416	5414	5412	5409	5407	5405	5403	5400	5398	5396
1.01	0.5394	5391	5389	5387	5385	5383	5380	5378	5376	5374
1.02	0.5371	5369	5367	5365	5362	5360	5358	5356	5354	5351
1.03	0.5349	5347	5345	5344	5340	5338	5336	5333	5331	5329
1.04	0.5327	5325	5322	5320	5318	5316	5313	5311	5309	5307
1.05	0.5305	5302	5300	5298	5296	5293	5291	5289	5287	5284
1.06	0.5282	5280	5278	5276	5273	5271	5269	5267	5264	5262
1.07	0.5260	5258	5255	5253	5251	5249	5247	5244	5242	5240
1.08	0.5238	5235	5233	5231	5229	5229	5224	5222	5219	5217
1.09	0.5215	5213	5211	5209	5206	5204	5202	5200	5197	5195
1.10	0.5193	5190	5188	5185	5183	5180	5178	5175	5173	5170
1.11	0.5168	5165	5163	5160	5158	5155	5153	5150	5148	5145
1.12	0.5143	5140	5137	5135	5132	5130	5127	5125	5122	5120
1.13	0.5118	5115	5113	5110	5108	5105	5103	5100	5098	5095
1.14	0.5093	5090	5088	5085	5083	5080	5078	5075	5073	5070
1.15	0.5068	5065	5062	5060	5057	5055	5052	5050	5047	5045
1.16	0.5042	5040	5037	5035	5032	5030	5027	5025	5022	5020
1.17	0.5017	5015	5012	5010	5007	5005	5002	5000	4997	4995
1.18	0.4992	4990	4987	4985	4982	4980	4977	4975	4972	4970
1.19	0.4967	4965	4962	4960	4957	4955	4952	4950	4947	4945
1.20	0.4942	4939	4936	4933	4930	4928	4925	4922	4919	4916
1.21	0.4913	4910	4907	4904	4901	4899	4896	4893	4890	4887
1.22	0.4884	4881	4878	4875	4872	4870	4867	4864	4861	4858
1.23	0.4855	4852	4849	4846	4843	4841	4838	4835	4832	4829
1.24	0.4826	4823	4820	4817	4814	4812	4809	4806	4803	4800
1.25	0.4797	4794	4791	4788	4785	4783	4780	4777	4774	4771
1.26	0.4768	4765	4762	4759	4756	4754	4751	4748	4745	4742
1.27	0.4739	4736	4733	4730	4727	4725	4722	4719	4716	4713
1.28	0.4710	4707	4704	4701	4698	4696	4693	4690	4687	4684
1.29	0.4681	4678	4675	4672	4669	4667	4664	4661	4658	4655

μ	0	1	2	3	4	5	6	7	8	9
1.30	0.4652	4649	4645	4642	4638	4635	4631	4628	4625	4621
1.31	0.4618	4614	4611	4607	4604	4601	4597	4594	4590	4586
1.32	0.4583	4580	4577	4573	4570	4566	4563	4559	4556	4553
1.33	0.4549	4546	4542	4539	4535	4532	4529	4525	4522	4518
1.34	0.4515	4511	4508	4505	4501	4498	4494	4491	4487	4484
1.35	0.4481	4477	4474	4470	4467	4463	4460	4457	4453	4450
1.36	0.4446	4443	4439	4436	4432	4429	4426	4422	4419	4415
1.37	0.4412	4408	4405	4402	4398	4395	4391	4388	4384	4381
1.38	0.4378	4374	4371	4367	4364	4360	4357	4354	4350	4347
1.39	0.4343	4340	4336	4333	4330	4326	4323	4319	4316	4312
1.40	0.4309	4305	4301	4298	4292	4288	4284	4280	4275	4271
1.41	0.4267	4263	4258	4254	4250	4246	4242	4237	4233	4229
1.42	0.4225	4221	4216	4212	4208	4204	4200	4195	4191	4187
1.43	0.4183	4178	4174	4170	4166	4162	4157	4153	4149	4145
1.44	0.4141	4136	4132	4128	4124	4120	4115	4111	4107	4103
1.45	0.4099	4094	4090	4086	4082	4077	4073	4069	4065	4061
1.46	0.4056	4052	4048	4044	4040	4035	4031	4027	4023	4018
1.47	0.4014	4010	4005	4001	3997	3993	3989	3985	3980	3976
1.48	0.3972	3968	3964	3959	3955	3951	3947	3943	3938	3934
1.49	0.3930	3926	3921	3917	3913	3909	3905	3900	3896	3892
1.50	0.3888	3883	3878	3874	3869	3864	3859	3854	3850	3845
1.51	0.3840	3835	3830	3825	3820	3816	3811	3806	3801	3796
1.52	0.3791	3786	3781	3776	3771	3766	3760	3755	3750	3745
1.53	0.3740	3735	3730	3724	3719	3714	3709	3704	3698	3693
1.54	0.3688	3683	3677	3672	3667	3662	3656	3651	3646	3640
1.55	0.3635	3630	3624	3619	3613	3608	3602	3597	3591	3586
1.56	0.3580	3574	3569	3563	3557	3552	3546	3540	3534	3528
1.57	0.3523	3517	3511	3506	3500	3494	3488	3482	3477	3471
1.58	0.3465	3459	3453	3447	3441	3435	3429	3423	3417	3411
1.59	0.3405	3399	3393	3386	3380	3374	3368	3362	3355	3349

Accessories

ACCESSORIES

Supplied with instrument

Operating Instructions

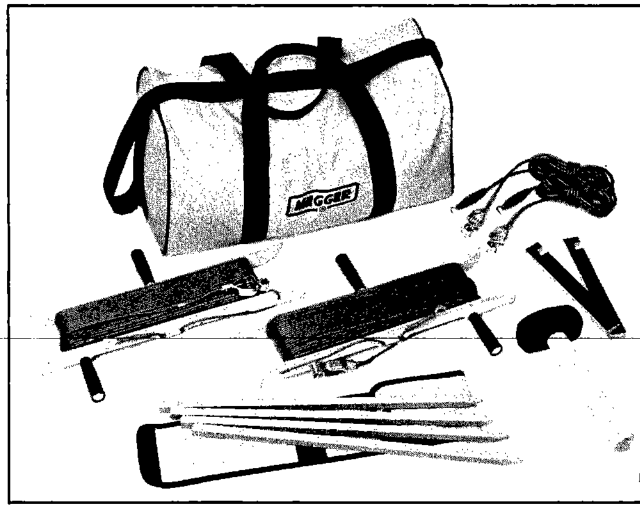
ACCESSORIES

Available as an optional extra

Earth testing accessory kit (ref. ET/KIT), part no. 6310-755 comprises a yellow bag and pouch containing:—

- a 1,13 kg (2½ lb) hammer
- four galvanized steel spikes 12 mm (½ in approx.) square section, 450 mm (17 in approx.) long
- two spike extractors
- 30 m (98½ ft approx.) of cable on a cable-winder, complete with connector and clip
- 50 m (164 ft approx.) of cable on a cable-winder, complete with connector and clip
- two 3 m (10 ft approx.) leads complete with connectors and clips

Reel of cable, 50 m long, part no. 6121-119



Earth Testing Accessory Kit

Instrument Repairs and Spare Parts

WARRANTY

All products supplied by BIDDLE Instruments are warranted against all defects in material and workmanship for a period of one year following shipment. Our liability is specifically limited to replacing or repairing, at our option, defective equipment. Equipment returned to the factory for repair will be shipped Prepaid and Insured. The warranty does not include batteries, lamps or tubes, where the original manufacturer's warranty shall apply. WE MAKE NO OTHER WARRANTY.

The warranty is void in the event of abuse.

REPAIRS

BIDDLE Instruments maintains a complete instrument repair service. Should this instrument ever require repairs, we recommend it be returned to the factory for repair by our instrument specialists. When returning instruments for repairs, either in or out of warranty, they should be shipped Prepaid and Insured, and marked for the attention of the Instrument Service Manager

Main Components List

R1	Resistor	1MΩ	± 0,25%	¼W
R2	Resistor	750kΩ	± 0,25%	¼W
R3	Resistor	250kΩ	± 0,25%	¼W
R4	Resistor	10Ω	± 0,25%	¼W
R5	Resistor	90Ω	± 0,25%	¼W
R6	Resistor	900Ω	± 0,25%	¼W
R7	Resistor	9kΩ	± 0,25%	¼W
R8	Resistor	270kΩ	± 5%	⅓W
R9	Resistor	20kΩ	± 2%	½W
R10	Resistor	9,1kΩ	± 2%	½W
R11	Resistor	20kΩ	± 2%	½W
R12	Resistor	1MΩ	± 5%	⅓W
R13	Resistor	12kΩ	± 1%	¼W
R14	Resistor	51,1kΩ	± 1%	¼W
R15	Resistor	1,8kΩ	± 5%	⅓W
R16	Resistor	10kΩ	± 0,3%	¼W
R17	Resistor	10kΩ	± 0,3%	¼W
R18	Resistor	10kΩ	± 5%	⅓W
R19	Resistor	10kΩ	± 0,3%	¼W
R20	Resistor	511kΩ	± 1%	¼W
R21	Resistor	10kΩ	± 5%	⅓W
R22	Resistor	909kΩ	± 1%	¼W
R23	Resistor	47kΩ	± 1%	¼W
R24	Potentiometer	10kΩ	± 10%	¾W
R25	Resistor	68kΩ	± 5%	⅓W
R26	Resistor	2,2MΩ	± 10%	⅓W
R27	Resistor	1,5kΩ	± 5%	⅓W
R28	Resistor	22kΩ	± 5%	⅓W
R29	Resistor	100kΩ	± 5%	⅓W
R30	Resistor	47kΩ	± 5%	⅓W
R31	Resistor	10kΩ	± 5%	⅓W
R32	Resistor	10kΩ	± 5%	⅓W
R33	Resistor	47kΩ	± 5%	⅓W
R34	Resistor	39,2kΩ	± 1%	¼W
R35	Potentiometer	10kΩ	± 10%	¾W
R36	Resistor	39kΩ	± 5%	⅓W
R37	Resistor	120kΩ	± 1%	¼W
R38	Resistor	100kΩ	± 1%	¼W
R39	Resistor	10kΩ	± 5%	⅓W
R40	Resistor	143Ω	± 0,25%	½W
R41	Resistor	1kΩ	± 0,25%	¼W
R42	Resistor	143Ω	± 0,25%	½W
R43	Resistor	1kΩ	± 0,25%	¼W
R44	Resistor	56,2Ω	± 1%	¼W
R45	Resistor	15kΩ	± 5%	¼W
R46	Resistor	990Ω	± 0,25%	¼W
R47	Resistor	990Ω	± 0,25%	¼W
R48	Resistor	1MΩ	± 5%	⅓W
R49	Resistor	1MΩ	± 5%	⅓W
R50	Resistor	4,7kΩ	± 2%	½W
R51	Resistor	4,7kΩ	± 2%	½W
R52	Resistor	10kΩ	± 5%	⅓W
R53	Resistor	1,5kΩ	± 5%	⅓W
R54	Resistor	100kΩ	± 5%	⅓W
R55	Resistor	47kΩ	± 5%	⅓W
R56	Resistor	4,7MΩ	± 5%	⅓W
R57	Resistor	4,7MΩ	± 5%	⅓W
R58	Resistor	2,7kΩ	± 1%	¼W
R59	Resistor	2,7kΩ	± 1%	¼W
R60	Resistor	47kΩ	± 5%	⅓W
R61	Resistor	47kΩ	± 5%	⅓W
R62	Resistor	1MΩ	± 5%	⅓W
R63	Resistor	820Ω	± 5%	⅓W
R64	Resistor	2,7kΩ	± 5%	⅓W
R65	Resistor	47kΩ	± 5%	⅓W
R66	Resistor	47kΩ	± 5%	⅓W
R67	Resistor	560Ω	± 5%	⅓W
R68	Resistor	1,5kΩ	± 5%	⅓W
R69	Resistor	560Ω	± 5%	⅓W

R70	Resistor	150Ω	±5%	⅓W
R71	Resistor	10Ω	±5%	⅓W
R72	Resistor	100Ω	±5%	⅓W
R73	Resistor	270kΩ	±5%	⅓W
R74	Resistor	1,5kΩ	±5%	⅓W
R75	Resistor	100Ω	±5%	⅓W
R76	Resistor	39Ω	±10%	5W
R77	Resistor	560Ω	± 5%	⅓W
R78	Resistor	560Ω	± 5%	⅓W
R79	Resistor	150Ω	±5%	⅓W
R80	Resistor	10kΩ	±5%	⅓W
R81	Resistor	2,7kΩ	±5%	⅓W
C1	Capacitor	100nF	± 10%	160V
C2	Capacitor	4,7μF	± 10%	63V) *
C3	Capacitor	4,7μF	± 10%	63V)
C4	Capacitor	220nF	± 10%	100V
C5	Capacitor	1μF	± 10%	63V
C6	Capacitor	1μF	± 10%	63V
C7	Capacitor	1μF	± 10%	63V
C8	Capacitor	4,7μF	± 10%	63V
C9	Capacitor	470nF	± 10%	100V
C10	Capacitor	4,7μF	± 10%	63V
C11	Capacitor	2,2μF	63V electrolytic	
C12	Capacitor	22nF	± 5%	400V
C13	Capacitor	47pF	± 2%	63V
C14	Capacitor	10nF	± 10%	100V
C15	Capacitor	15nF	± 10%	100V
C16	Capacitor	15nF	± 10%	100V
C17	Capacitor	2,2μF	63V electrolytic	
C18	Capacitor	47pF	± 2%	63V
C19	Capacitor	10μF	25V electrolytic	
C20	Capacitor	220μF	16V electrolytic	
C21	Capacitor	220μF	16V electrolytic	
C22	Capacitor	2,2μF	63V electrolytic	
C23	Capacitor	33nF	± 10%	100V

*Matched to within ± 1%

C24	Capacitor	10μF	100V electrolytic	
C25	Capacitor	10nF	±10%	100V
C26	Capacitor	10nF	±10%	100V
C27	Capacitor	10nF	±10%	100V
C28	Capacitor	10nF	±10%	100V
C29	Capacitor	10μF	100V electrolytic	
C30	Capacitor	100μF	40V electrolytic	
C31	Capacitor	220μF	16V electrolytic	
C32	Capacitor	0,1μF	25V electrolytic	
C33	Capacitor	220μF	16V electrolytic	
C34	Capacitor	0,1μF	25V electrolytic	
C35	Capacitor	100μF	40V electrolytic	
C36	Capacitor	47pF	±10%	630 V
C37	Capacitor	10nF	±10%	100 V
C38	Capacitor	10μF	40 V electrolytic	
C39	Capacitor	10μF	40 V electrolytic	
C40	Capacitor	10nF	±10%	100V
C41	Capacitor	10nF	±10%	100V
D1 to D6	Diode	1N4148		
D9 to D14	Diode	1N4148		
D15	Light emitting diode			
D16	Light emitting diode			
D17	Zener diode	1N5366B		
D18 to D22	Diode	1N4004		
D23	Diode	1N4148		
D24	Diode	1N4004		
D25	Diode	1N4004		
D26	Diode	1N4148		
D27	Zener diode	BZY88C27V		
D29 to D31	Diode	1N4004		
D34	Diode	1N4004		
D35	Diode	BA158		
D36	Diode	BA158		
D37	Diode	1N4004		

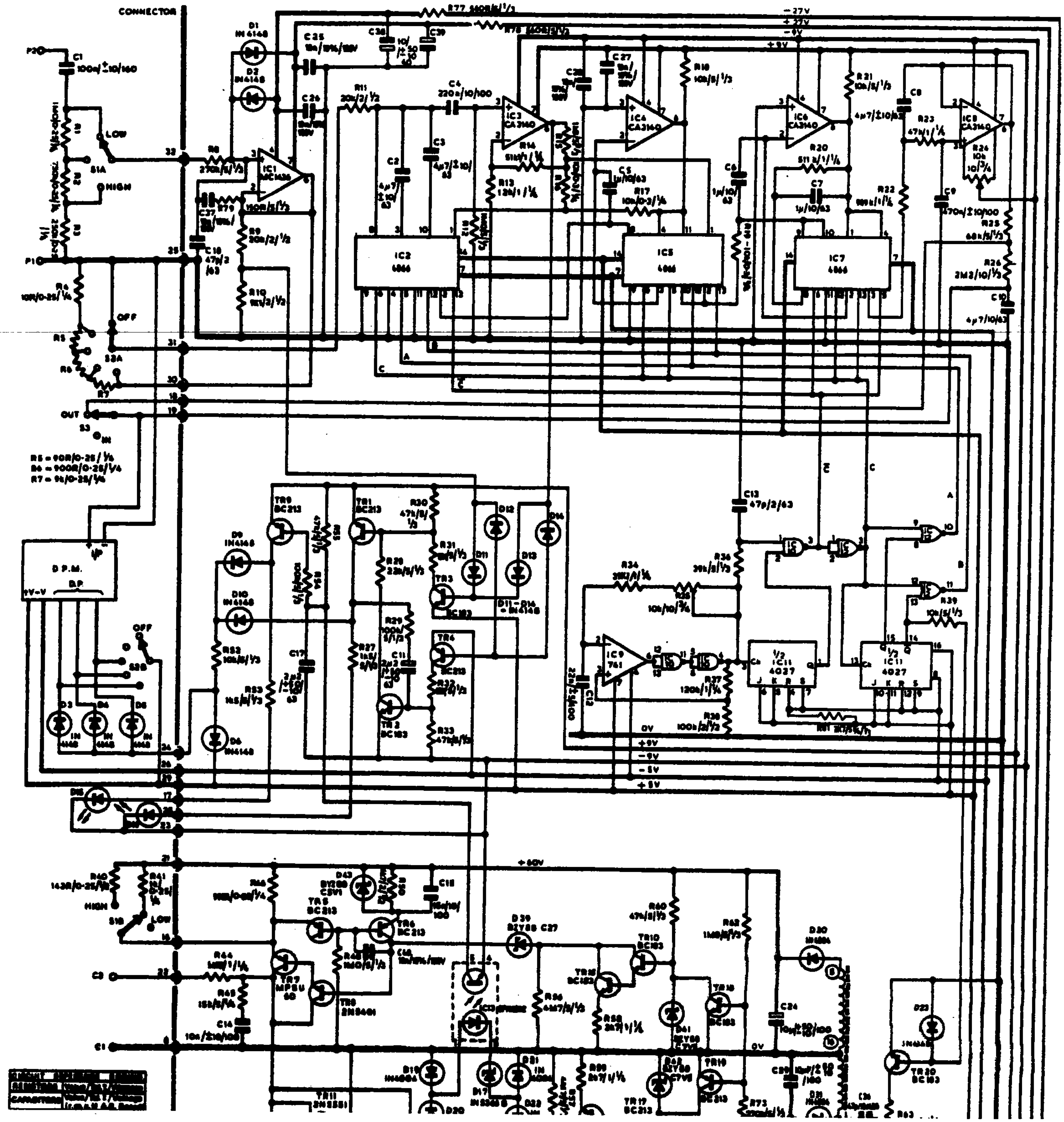
Main Components List

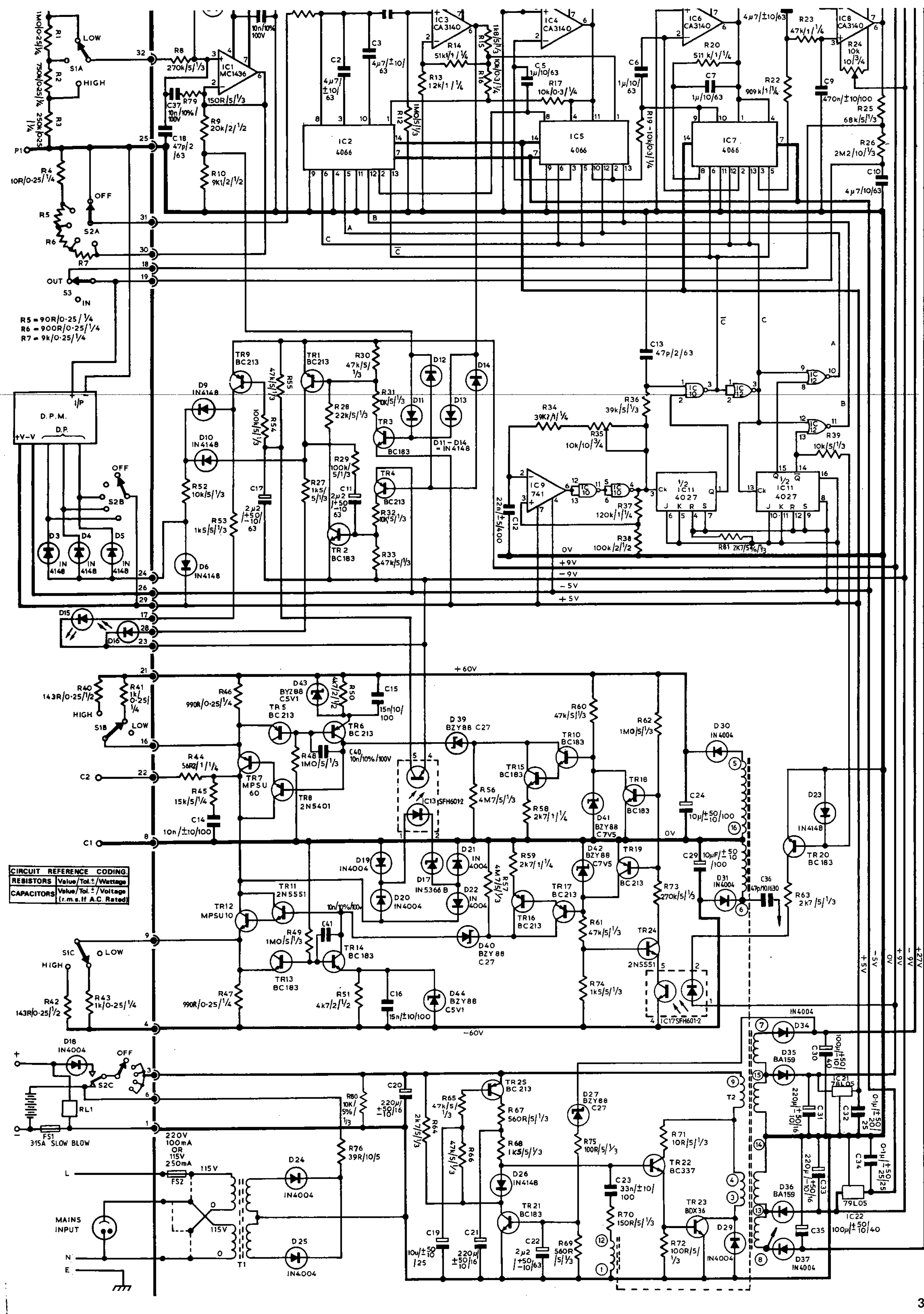
D39	Zener diode	BZY88C27V
D40	Zener diode	BZY88C27V
D41	Zener diode	BZY88C7V5
D42	Zener diode	BZY88C7V5
D43	Zener diode	BZY88C5V1
D44	Zener diode	BZY88C5V1
TR1	Transistor	BC213
TR2	Transistor	BC183
TR3	Transistor	BC183
TR4 to TR6	Transistor	BC213
TR7	Transistor	MPSU60
TR8	Transistor	2N5401
TR9	Transistor	BC213
TR10	Transistor	BC183
TR11	Transistor	2N5551
TR12	Transistor	MPSU10
TR13 to TR15	Transistor	BC183
TR16	Transistor	BC213
TR17	Transistor	BC213
TR18	Transistor	BC183
TR19	Transistor	BC213
TR20	Transistor	BC183
TR21	Transistor	BC183
TR22	Transistor	BC337
TR23	Transistor	BDX36
TR24	Transistor	2N5551
TR25	Transistor	BC213
IC1	Integrated circuit	MC1436CG
IC2	Integrated circuit	4066 CMOS
IC3	Integrated circuit	CA3140E
IC4	Integrated circuit	CA3140E
IC5	Integrated circuit	4066 CMOS
IC6	Integrated circuit	CA3140E
IC7	Integrated circuit	4066 CMOS
IC8	Integrated circuit	CA3140E
IC9	Integrated circuit	741 8PIN
IC10	Integrated circuit	4011 CMOS
IC11	Integrated circuit	4027
IC12	Integrated circuit	4001
IC13	Integrated circuit	SFH601-2
IC17	Integrated circuit	SFH601-2
IC21	Integrated circuit	78L05CP
IC22	Integrated circuit	79L05CP
FS1	Fuse	3,15A(T) Type F286
FS2	Fuse DET2—	100mA Type 19180
	DET2/110—	250mA Type F270

Digital Panel Meter Components

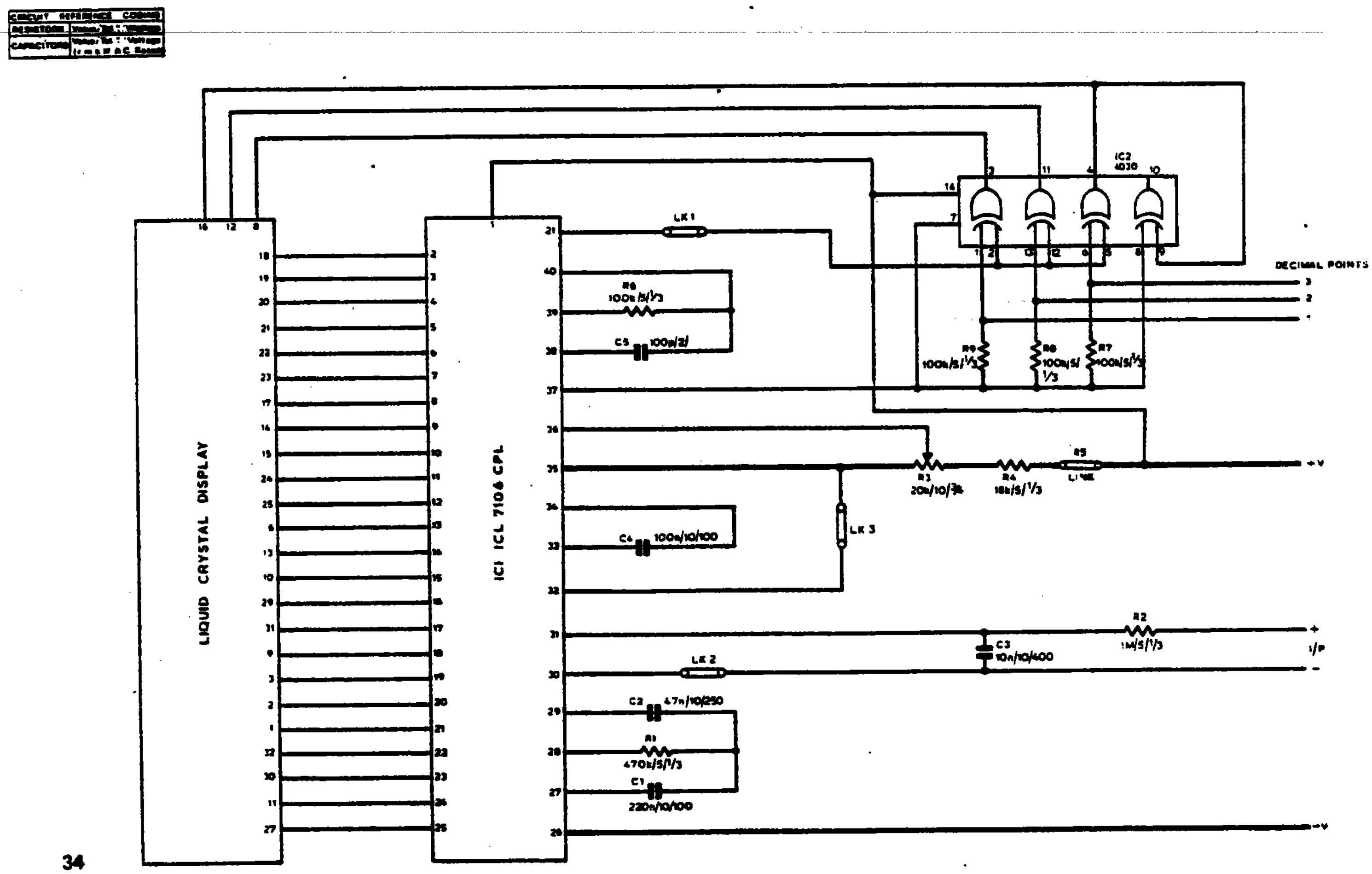
R1	Resistor	470kΩ	± 5%	⅓W
R2	Resistor	1MΩ	± 5%	⅓W
R3	Potentiometer	20kΩ	± 10%	¾W
R4	Resistor	18kΩ	± 5%	¼W
R5	Link			
R6	Resistor	100kΩ	± 5%	⅓W
R7	Resistor	100kΩ	± 5%	⅓W
R8	Resistor	100kΩ	± 5%	⅓W
R9	Resistor	100kΩ	± 5%	⅓W
C1	Capacitor	220nF	± 10%	100V
C2	Capacitor	47nF	± 10%	250V
C3	Capacitor	10nF	± 10%	400V
C4	Capacitor	100nF	± 10%	100V
C5	Capacitor	100pF	± 2%	63V
IC1	Integrated circuit	ICL7106CPL		
IC2	Integrated circuit	CMOS 4070		

Main Circuits Diagram




CIRCUIT REFERENCE CODING.
RESISTORS Value/Tol.±/Wattage
CAPACITORS Value/Tol.±/Voltage (r.m.s. if A.C. Rated)
R5 = 90R/0·25/1/4
R6 = 900R/0·25/1/4
R7 = 9k/0·25/1/4
D.P.M.
MAINS INPUT
+60V
-60V
0V
+9V
-9V
-5V
+5V
+27V
-27V

Panel Meter Circuit Diagram



Biddle INSTRUMENTS
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MEGGER