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ELECTRONIC MULTIMETER CONSTRUCTION

FOR THE HOME CONSTRUCTOR

Complete Instructions
& Full Size Wiring Diagrams
Showing how to build
both Battery Powered and
Mains Operated Electronic
Multimeters

BERNARDS RADIO
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ELECTRONIC MULTIMETER CONSTRUCTION

It is a well-known fact that the input resistance of a Valve Voltmeter is far higher than that which can be obtained with a conventional moving coil instrument. It enables accurate voltage measurements to be taken in instances where the conventional meter would impose an excessive drain on the circuit under test. A good circuit need not be expensive, and full constructional details are given for both mains and battery operated models.

Since both instruments rely upon the same basic circuit, this is given in Fig. 1. Here it will be seen that the two valves and two resistors form the arms of a bridge, with a meter and shunt connected between the anodes of the valves. When the two anode voltages are equal, no current will flow through the meter or shunt, and the circuit will be balanced—this balanced condition is accomplished by feeding the H.T. supply through a 5kΩ potentiometer which is adjusted until the meter reads zero.

Should a positive voltage be applied to the grid of V1, the anode current will increase. This current has to flow through the 1kΩ resistor which is common to both valves. The increased voltage drop across this resistor is applied to the grid of V2, in the form of a negative bias, which reduces the anode current through this valve.

Voltage is measured as shown by Fig. 2. The meter is set for full scale deflection with 0.67 of a volt applied to the grid, so with one volt applied to a resistance of 1.5MΩ tapped at 1MΩ, a full scale deflection will result. With the same resistance tapped at 100kΩ, and 10 volts applied, a full scale deflection will again be obtained.

Resistance measurement utilizes the circuit shown by Fig. 3. In this case, 1% of the H.T. voltage is applied to the grid of V1, and the " Sensitivity " control set so that a full scale deflection is obtained. The unknown resistor is then shunted across the standard and the currents will divide accordingly—i.e. In inverse proportion to the resistance—With a standard of 100 ohms a resistance of 10,000 ohms will cause a 1% fall in the meter reading, whilst a resistance of 1 ohm would reduce the reading by 99 per cent. 100 ohms would cause the reading to fall to half scale.

Insulation is measured in another simple manner, the voltage drop between H.T. and grid is applied to the insulation being measured, the leakage current through the insulation causes a voltage to develop across the grid resistor as shown in Fig. 4. The H.T. voltage is 100 times the full scale voltage of the grid circuit, so that if a resistance 100 times that of the standard be placed in the circuit, a full scale reading will be obtained. One of 200 times will give a reading of half scale, and should the value be 10,000 times the standard, a 1% deflection would result.

Choice of instrument case is a matter for the constructor since some people may have a case handy; others may prefer to make one out of wood. No matter what type of case is used, it is essential that the front panel be made of metal. The prototype was built into a " 9 × 12 " instrument case made by Kendall & Mousley. These cases are 9″ × 12″ × 9″ and give a panel size that is ample for the layout of the various components.

Fig. 5 shows the finished front panel, and Fig. 6 the details for marking out and drilling, the only difference in appearance between the mains and battery models being that the latter has fewer ranges on the " Selector switch," and uses four terminals instead of three. Four terminals are specified in order that the switching may be kept to a minimum, and also to reduce leakage currents.

Belling-Lee type L.1004/11 terminals are specified, and have been found ideal for this job. Leakage is very low, and they have a key-way which locks them to the panel, and prevents them turning after the instrument is assembled.

The appearance of the front panel is very important. The front panel is the only part of the instrument which is constantly exposed to view, and the constructor is well advised to take considerable care over the finish.

A good quality enamel presents a very pleasing appearance and is easier to keep clean than a crackle finish. A crackle finish adds that " professional " look, and may be achieved by using a special paint called PANL. There is one serious disadvantage to the crackle finish—the difficulty of applying transfers when labelling the various controls.

Suitable transfers which give all the required names can be found in the packets of Panel-Signs made by Data Publications Ltd.—the No. 2 Packet being a selection of names for test gear. These transfers are easy to apply, and can be rendered permanent with the aid of a special varnish.

BATTERY OPERATED MODEL

The complete theoretical diagram for the Battery Model is shown in Fig. 7 and no doubt some constructors will work direct from this diagram.

The ranges provided by this instrument are:—

Resistance Measurement.

First Division	Centre Scale	Full Scale
5Ω	100Ω	10kΩ
50Ω	1kΩ	100kΩ
500Ω	10kΩ	1MΩ

Insulation Measurement.

100kΩ to 10MΩ
1MΩ to 100MΩ
10MΩ to 1000MΩ

Voltage Measurement.

0 to 1v
0 to 10v
0 to 100v

Input resistance of 1.5MΩ

A " Volts × 10 " terminal is also fitted so that a multiplying factor of 10 can be introduced which increases the input resistance to 15MΩ.

Meter wiring, " Set Zero " control, " Sensitivity " control, and meter reversing switch are shown in Fig. 8. The two 5kΩ anode load resistors can be mounted as shown direct to the tags of the zero control. Leads should be soldered to the wire ends, and taken direct to the " Sensitivity " control. A reversing switch caters for the measurement of negative voltages.

A miniature chassis for the two valves can be made from a small piece of scrap metal about 2″ square. Suitable holes should be drilled for the mounting of two McMurdo B7G valve holders, and the unit wired as shown in Fig. 9. It will be seen that both valves are connected as triodes. A point which may puzzle some readers is that H.T.— is connected to the control grid instead of the heater.

A 1kΩ resistor, which joins the heater and control grid of V2 acts as a bias resistor and the grid is connected to the negative end. Both L.T.— and H.T.— lines should be taken to the switch on the panel, since the ON/OFF switch breaks both circuits. This is important as the DL96 valves can be ruined if the heater voltage is cut off with the H.T. still applied. The indicator lamp should be wired in parallel with the two valve heaters, the bulb being of the 1.5 volt low current type.

Next the "Selector switch" and terminals will require wiring. The standard resistors can be wired direct to the tags of the switch.

This can be done quite simply, but it is recommended that the resistor leads should be insulated with sleeving in order to reduce fault liability. The 13.5MΩ resistor will be in two sections, one of 3.5MΩ and the other of 10MΩ. These resistors should be wired direct to the terminals (between "Volts" and "Volts × 10"), where they form a series multiplier to increase the input resistance on certain ranges; they also increase the maximum voltage which can be measured to 1,000v. The terminals recommended will stand this voltage, but care should be taken to use a lead that has sufficiently good insulation to prevent the user getting a shock.

The 5MΩ resistor in the Volts circuit can be joined between the "Volts" terminal and the first tag on the selector switch. The switch can best be wired before it is fitted to the instrument, and the requisite leads be left for finally wiring into the circuit. Earth points on the switch should be joined together and taken to the panel and to the H.T.– lead on the ON/OFF switch—(on the instrument side and NOT the battery side). The H.T. positive lead should be connected to H.T. at any convenient point in the circuit.

Having completed the unit, all the wiring and connections should be checked prior to switching on. This checking should be done with great care as the meter can very easily be damaged. Having corrected any faults, the battery should be connected. The Ever-Ready B114 is suitable. The sensitivity control should be set at ZERO and the range switch set to one of the voltage positions. The instrument can now be switched on. Slowly advance the "Sensitivity" control and at the same time move the pointer back to zero with with the "Set Zero" control; continue until the "Sensitivity" control is set at maximum. Return the "Sensitivity" control to zero, and switch to one of the Ohms ranges. Now adjust the "Sensitivity" control until a full scale reading is obtained. The instrument is now set up and ready for use. There will be slight differences between the various Ohms ranges due to the small inaccuracies in the standard resistors. If 1% standard resistors have been used, then the drift from range to range is negligible.

Measurement of A.V.C. voltages can be undertaken with ease, and this is best done on the "Volts × 10" range since the input resistance is then 15MΩ. The load imposed is so small that the error caused on the average A.V.C. circuit is well under 10%.

Accuracy of the Voltage ranges will vary with the condition of the battery; since the input resistance is so high, errors due to loading the circuit with the meter can be neglected, and under most conditions will be within 5%.

MAINS OPERATED MODEL

This instrument, whilst being similar to the Battery Model, is slightly more complex; a complete circuit diagram being given in Fig. 10. The ranges provided are:—

Volts.

0 - 1 volt.
0 - 3 ,,
0 - 10 ,, } Input resistance 1MΩ.
0 - 30 ,,
0 - 100 ,,

A " Volts × 10 " terminal is provided, which increases the input resistance to 10MΩ and allows voltages up to 1,000v to be measured.

Resistance.

First Division	Centre Scale	Full Scale
5Ω	100Ω	10kΩ
50Ω	1kΩ	100kΩ
500Ω	10kΩ	1MΩ

Insulation.

100kΩ to 10MΩ
1MΩ to 100MΩ
10MΩ to 1000MΩ

For this model the valves chosen are both type EF37A (Mullard). The EF37A is metallised and has a top cap grid which renders it particularly suitable for this sort of circuit, since anode to grid leakage is eliminated. This point is worthy of further consideration.

On the low voltage range the meter has an input resistance of 1MΩ. Should the leakage resistance between anode and grid be near 100MΩ, the error would be equal to the full scale deflection of the meter, and even 1000MΩ would give a 10% deflection of the pointer. In the case of theEF37A, the grid cap is surrounded by earthed metallising, and any slight leakage of H.T. is short circuited to " earth " before reaching the grid.

The circuit is a simple one, but it overcomes some of the difficulties encountered with the battery version. For instance, the H.T. line is stabilised so that the accuracy of the meter is unaffected by small changes in supply voltage. A stabiliser valve cannot be used with the battery circuit because of the increased drain it would impose on the battery—this is unfortunate perhaps, but of course the Battery Model scores on portability, since it is independent of an external power supply.

This instrument is in two main parts, the front panel, on which the meter, terminals, and controls are mounted; and the chassis which carries the valves and mains transformer. Both units are interconnected by means of an Octal plug and socket.

The chassis is quite small, being only 6″ × 5″ × 2½″, but is nevertheless of ample size for the job and fits into the instrument case very easily. Details of marking out and drilling the chassis are shown in Fig. 11. The front panel is the same as the Battery Model (Fig. 6) except for the fact that only three terminals are fitted instead of four.

When drilling the chassis, a large grommet should be fitted near to the Mains Transformer to enable the leads to be fed through the chassis without any danger from chafed insulation. Hole (d) Fig. 11.

Four large holes (b), have to be cut, three of them for Octal valveholders, and the fourth to accommodate the 8-8μf electrolytic capacitor. Two holes (a) allow B.7.G valveholders to be fitted for the Rectifier and Stabiliser valves, whilst the remaining small holes, take the various mounting bolts.

If the instrument is going to be taken from place to place, it is advisable to use screened sockets, or better still, retaining clips to hold the two B.7.G valves in position. Under chassis wiring is shown in Fig. 12, with all valves and sockets viewed from the underside. Pins 1 and 8 of both valves should be connected together and taken to R15. (Not shown for clarity.)

All the wiring on the Range selector switch should be carried out across the tags themselves, and the resistors should not be mounted across a separate tag board—the resistor leads should be insulated with sleeving to prevent accidental short circuits.

An Oak S.0014 wafer switch was chosen since it combines a robust nature with excellent contact construction. Once the resistors have been mounted on the switch, there remain five leads which have to be connected to the rest of the circuit.

(1) Connects to the H.T. positive pin of the Octal Plug.
(2) Connects to the grid of V1 via a 10kΩ resistor, the resistor being soldered to the top cap clip.
(3) Should be connected to the earth pin on the Octal Plug.
(4) Connects to T1, the common terminal which is used for all tests.
(5) Should be wired to T2, the Positive terminal.

T2 should be joined to T3 by means of a 9MΩ 2W 5% resistor.

Setting up the instrument is exactly similar to the Battery Model, but a thorough check of all wiring and connections should be made before switching on for the first time.

BATTERY MODEL COMPONENTS

VARIABLE RESISTORS.

Ref.	*Value.*	*Manufacturer.*	*Type.*
VR1	5kΩ 2w	COLVERN	CLR 3001
VR2	5kΩ 2w	"	"

RESISTORS. T.S.L.

Ref.	*Value.*	*Rating.*	*Type.*	*Ref.*	*Value.*	*Rating.*	*Type.*
R1	3.5MΩ	2w 5%	R	R8	900kΩ	1w 1%	PR
	10MΩ	2w 5%	R	R9	90kΩ	1w 1%	PR
R2	5MΩ	2w 2%	I	R10	10kΩ	1w 1%	PR
R3	900kΩ	1w 1%	PR	R11	10kΩ	½w 10%	R
R4	90kΩ	1w 1%	PR	R12	5kΩ	1w 5%	R
R5	9kΩ	1w 1%	PR	R13	5kΩ	1w 5%	R
R6	900Ω	½w 1%	PR	R14	1kΩ	½w 10%	R
R7	100Ω	½w 1%	PR				

VALVES.

Qty.	*Type.*	*Manufacturer.*
2.	DL96	MULLARD

SUNDRIES.

Qty.	*Type.*	*Ref.*	*Manfacturer.*
1.	Terminal	L004/11/Black	Belling-Lee
3.	"	L004/11/Red	"
1.	Pointer Knob	K.107	A. F. Bulgin & Co. Ltd.
2.	Knobs	K94	" " " "
1.	Pilot Lamp Holder	D430/RED/C	" " " "
1.	Instrument Case	"9-12"	Kendall & Mousley
2.	B.7.G valveholders	XM7/UC-1	McMurdo Instruments Ltd.
2.	Screening Cans (Optional)	45	" " "
1.	Packet of PANEL-SIGNS		Data Publications

SWITCHES.

Qty.	*Ref.*	*Type.*	*Manufacturer.*
1.	S.267	D.P.S.T. Toggle.	A. F. Bulgin & Co. Ltd.
1.	S.270	D.P.D.T. Change Over.	" " "
1.	4 Bank with ⅜″ spacers.	9 Way. Wafer Switch.	A. B. Metal Products Ltd.

METER.

PULLIN 0-100 μA. movement with specially calibrated scales. Kendall & Mousley

MAINS MODEL COMPONENTS

VARIABLE RESISTORS.

Ref.	*Value.*	*Manufacturer.*	*Type.*
VR1	5kΩ 2w	COLVERN	CLR 3001
VR2	1kΩ 2w	„	„

RESISTORS. T.S.L.

Ref.	*Value.*	*Rating.*	*Type.*	*Ref.*	*Value.*	*Rating.*	*Type.*
R1	9MΩ	2w 5%	R	R10	90kΩ	½w 1%	PR
R2	700kΩ	1w 1%	PR	R11	900kΩ	1w 1%	PR
R3	200kΩ	½w 1%	PR	R12	10kΩ	½w 10%	R
R4	70kΩ	½w 1%	PR	R13	5kΩ	1w 5%	R
R5	20kΩ	½w 1%	PR	R14	5kΩ	1w 5%	R
R6	9kΩ	½w 1%	PR	R15	1kΩ	½w 10%	R
R7	900Ω	½w 1%	PR	R16	33kΩ	1w 20%	R
R8	100Ω	½w 1%	PR	R17	33kΩ	1w 20%	R
R9	10kΩ	½w 1%	PR				

VALVES.

Qty.	*Type.*	*Manufacturer.*
1.	EY91	MULLARD
1.	90C1	„
2.	EF37A	„

PLUGS AND SOCKETS.

Qty.	*Type.*	*Manufacturer.*
2.	B.7.G valveholders. XM7/UC-1	McMurdo Instruments Ltd.
3.	International Octal Valveholders.	„ „ „
1.	Octal plug Type P112.	A. F. Bulgin & Co. Ltd.
2.	Screening Cans (Optional) Type 45.	McMurdo Instruments Ltd.

SWITCHES.

Qty.	*Ref.*	*Type.*	*Manufacturer.*
1.	S.267	D.P.S.T. Toggle.	A. F. Bulgin & Co. Ltd.
1.	S.270	D.P.D.T. Change Over.	„ „ „ „
1.	S.0014	11 way. 4 pole Wafer.	N.S.F. - OAK Ltd.

MAINS TRANSFORMER.

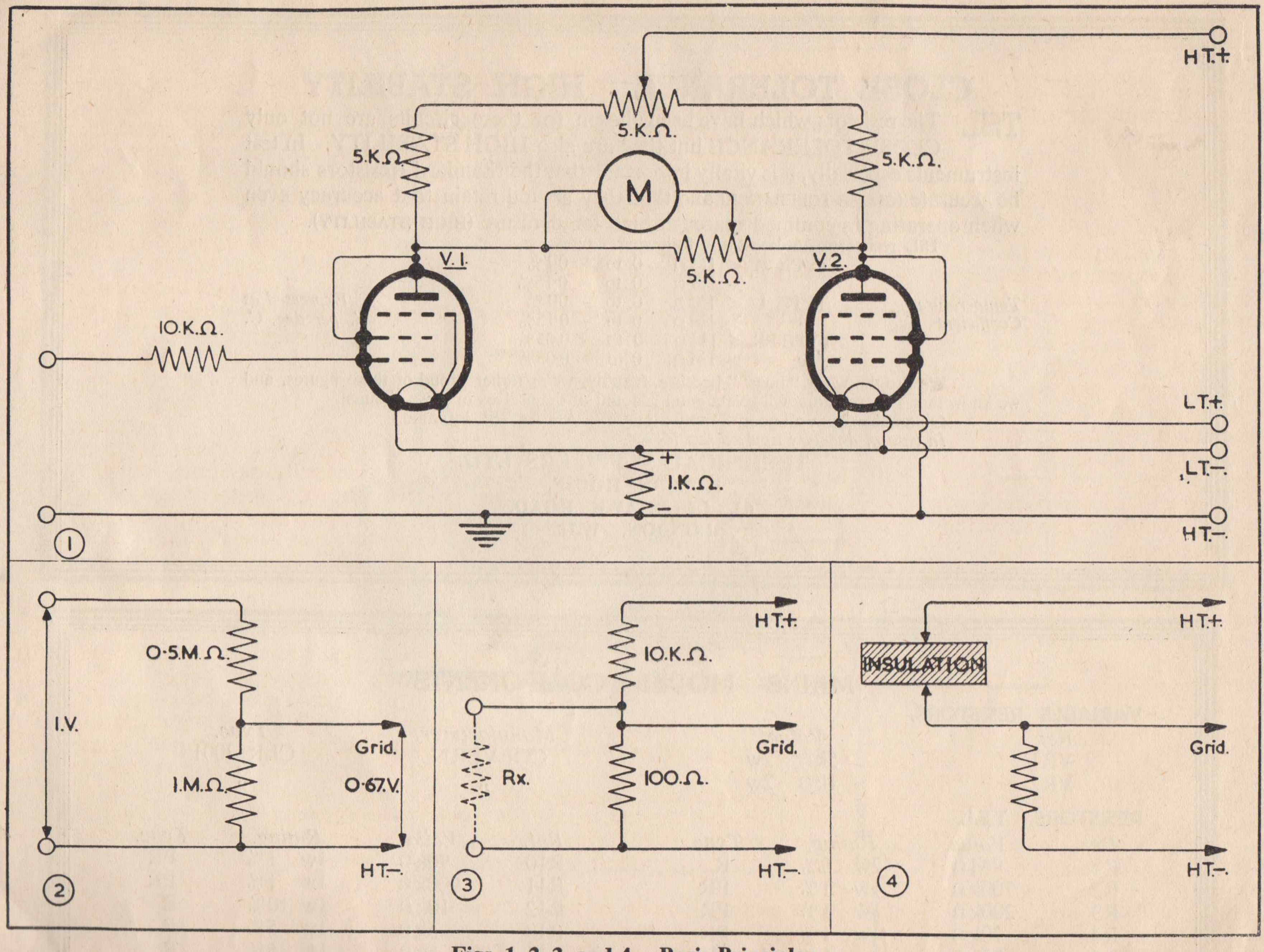
Ref.			
T.F.1.	Primary	230 volts	
	Secondaries	250 volts	30mA
		6.3v	1 A

METER.

PULLIN	0-100 μA. movement with specially calibrated scales.	Kendall & Mousley

SUNDRIES.

Qty.	*Type.*	*Ref.*	*Manufacturer*
1.	Terminal	L004/11/Black	Belling-Lee
2.	„	L004/11/Red	„ „
1.	Pointer Knob	K.107	A. F. Bulgin & Co. Ltd.
2.	Knobs	K94	„ „ „ „
1.	Pilot Lamp Holder.	D.430/RED/C	„ „ „ „
1.	Chassis 6″ × 5″ × 2½″		Kendall & Mousley
1.	Instrument Case	“ 9—12 ”	„ „ „
1.	Packet of PANEL SIGNS		Data Publications
1.	8—8μf 500v.w. Electrolytic capacitor	CE37PC	The Telegraph Condenser Co. Ltd.



Figs. 1, 2, 3, and 4. Basic Principles.

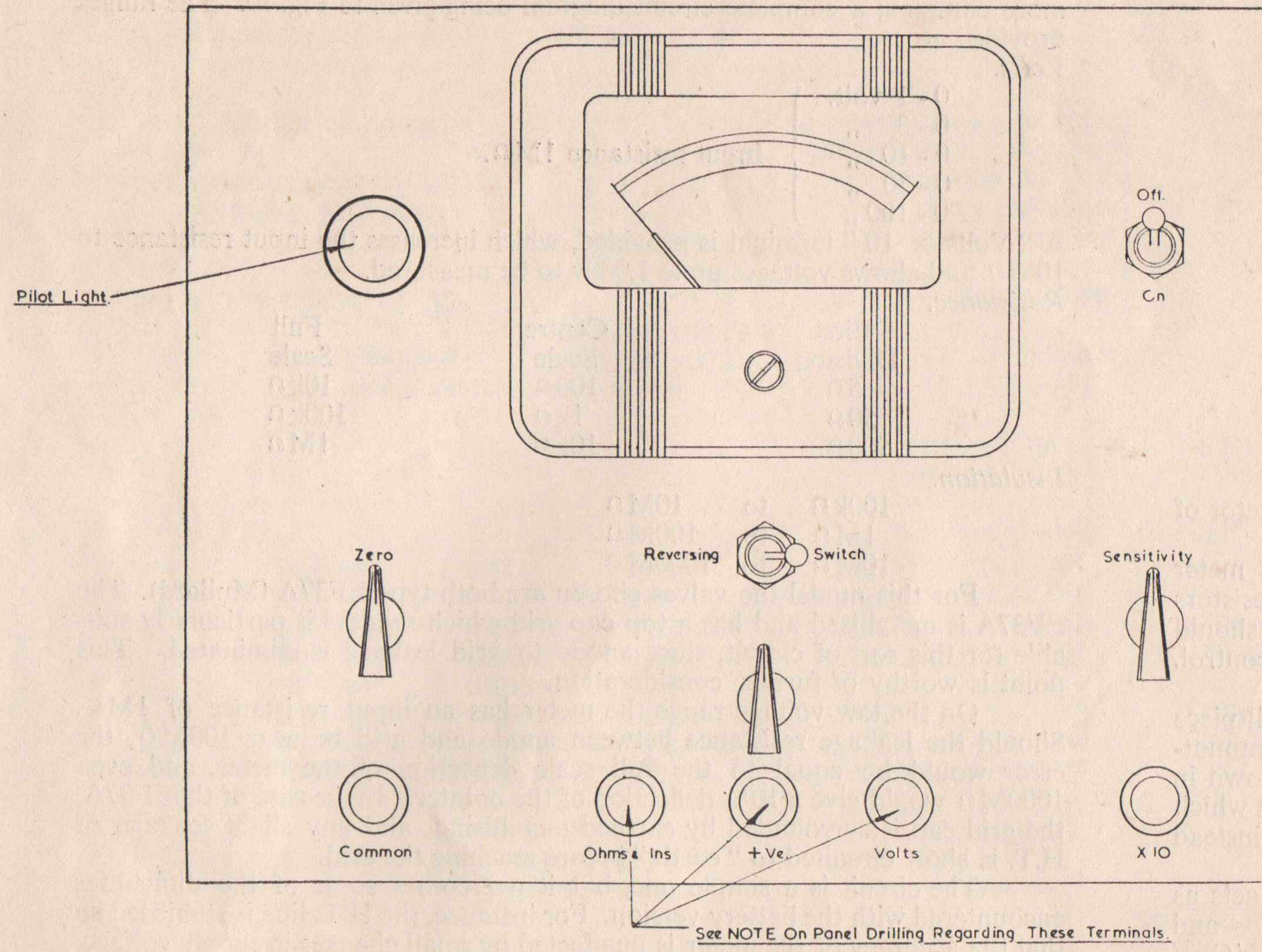
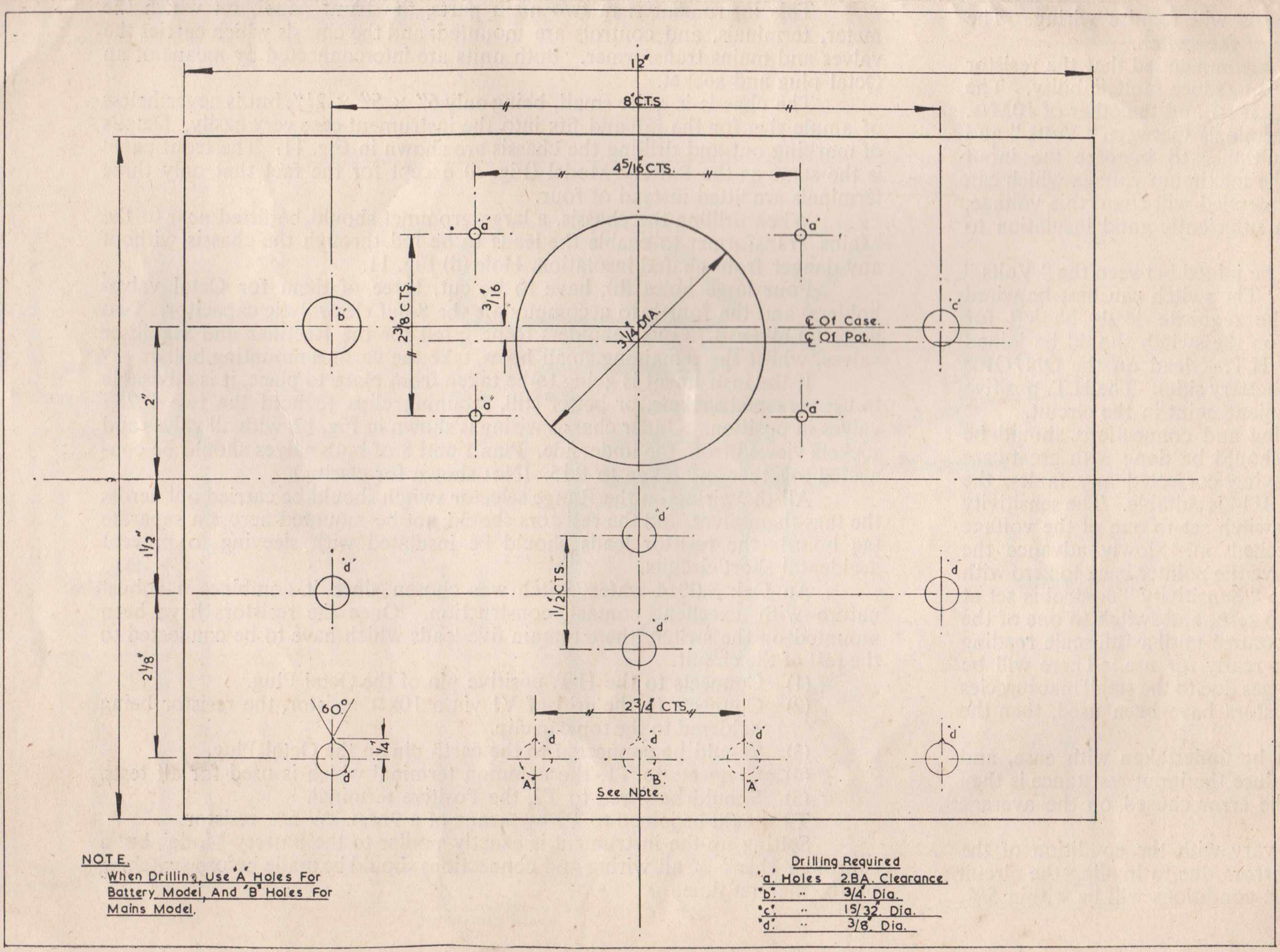


Fig. 5. The finished Front Panel.



NOTE.
When Drilling, Use 'A' Holes For Battery Model, And 'B' Holes For Mains Model.

Drilling Required

'a'	Holes	2.BA. Clearance.
'b'	..	3/4. Dia.
'c'	..	15/32" Dia.
'd'	..	3/8" Dia.

Fig. 6. Front Panel Measurements.

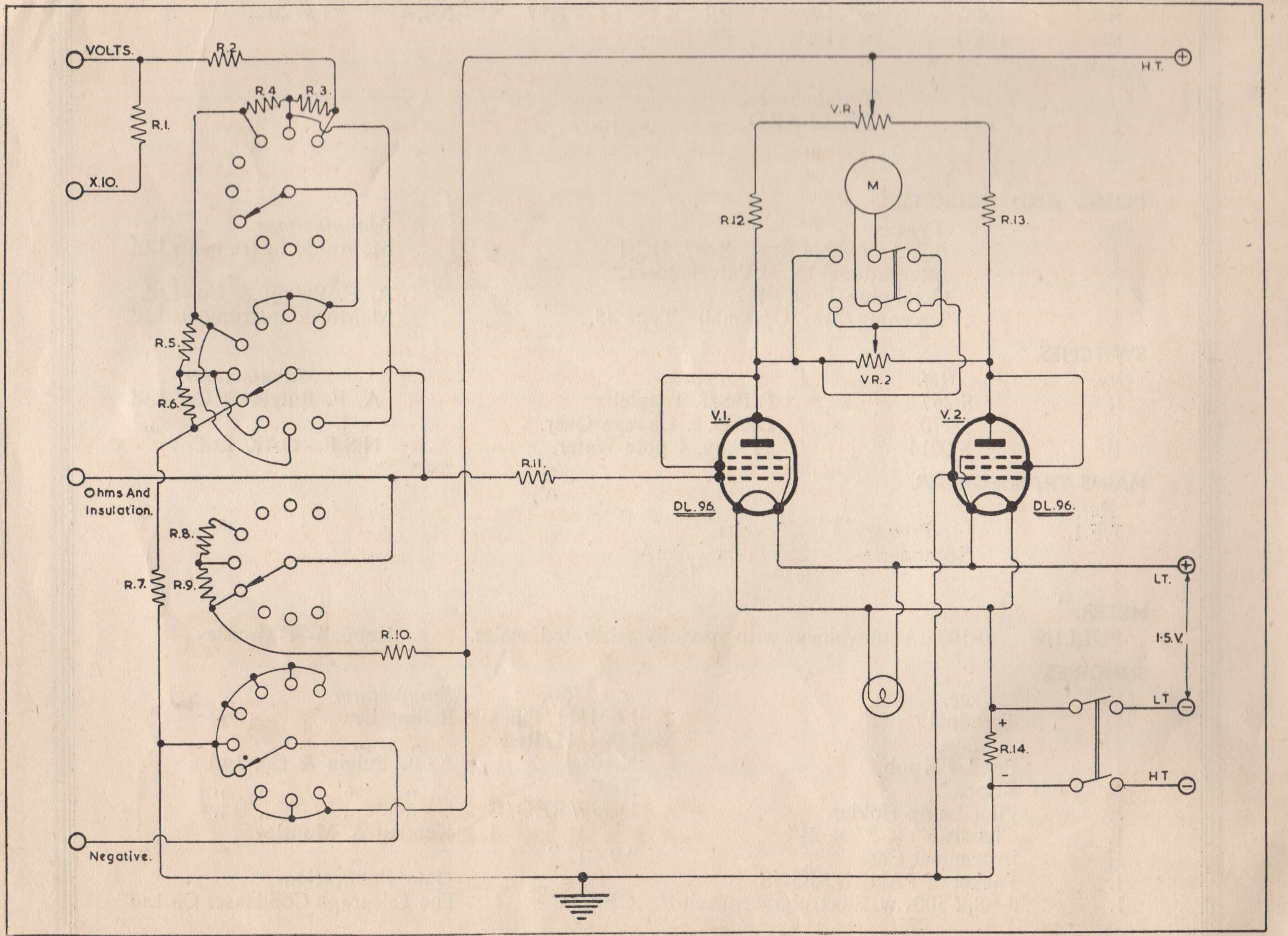
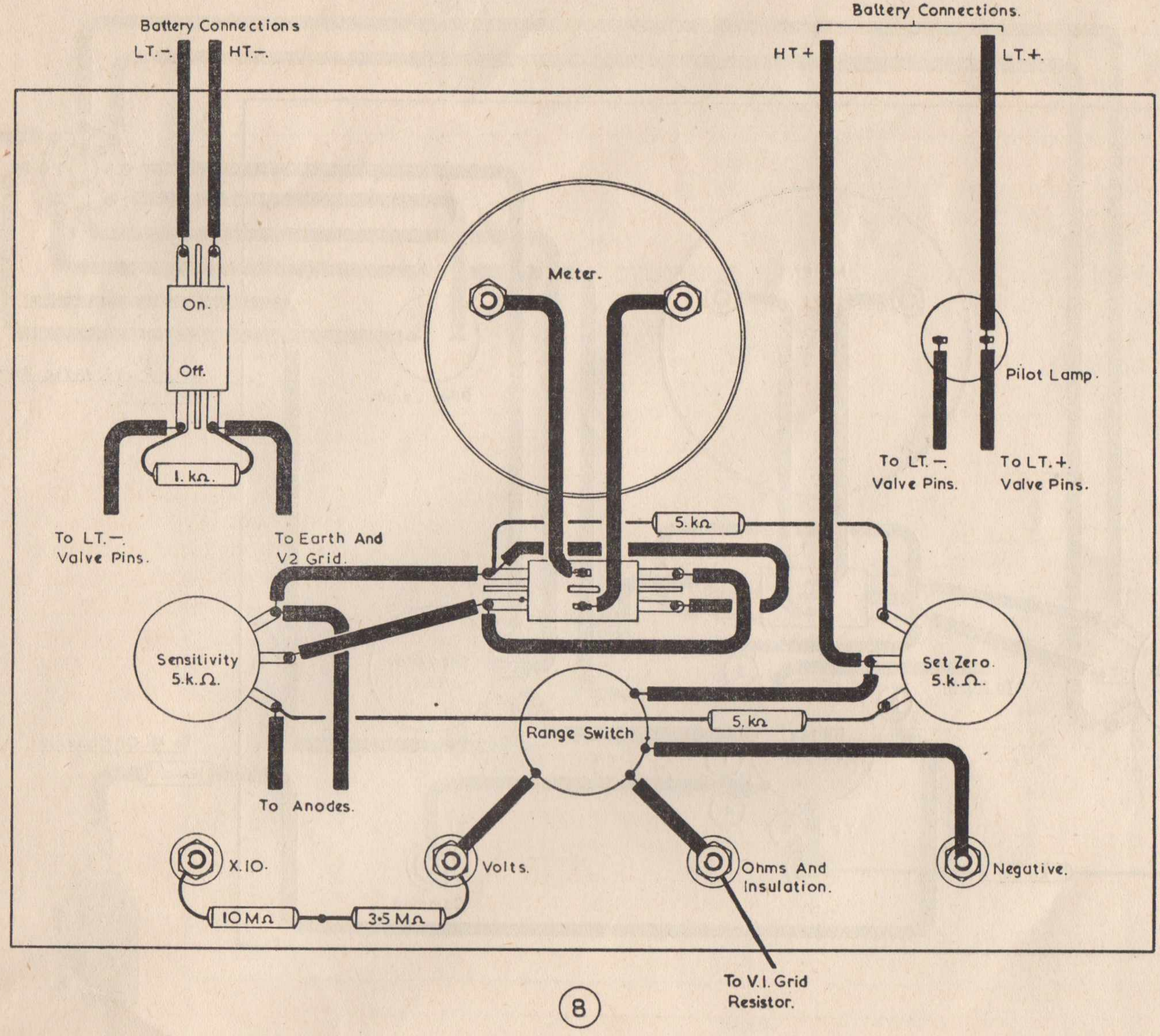


Fig. 7. The Battery Model.



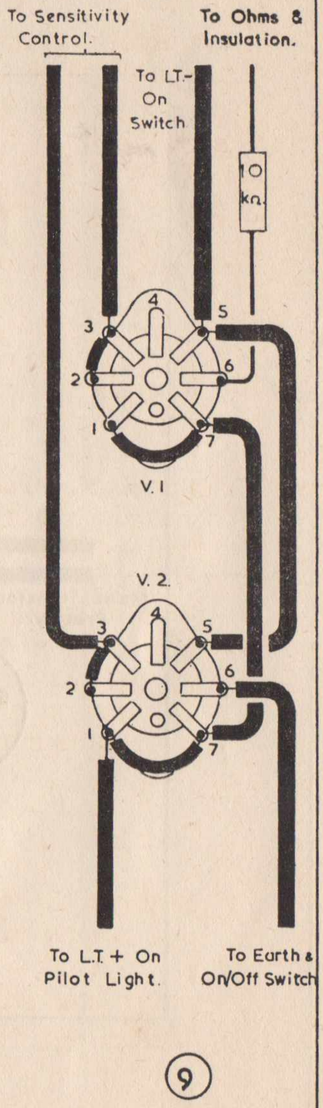


Fig. 8. Front Panel wiring. Fig. 9. Valve Base connections.

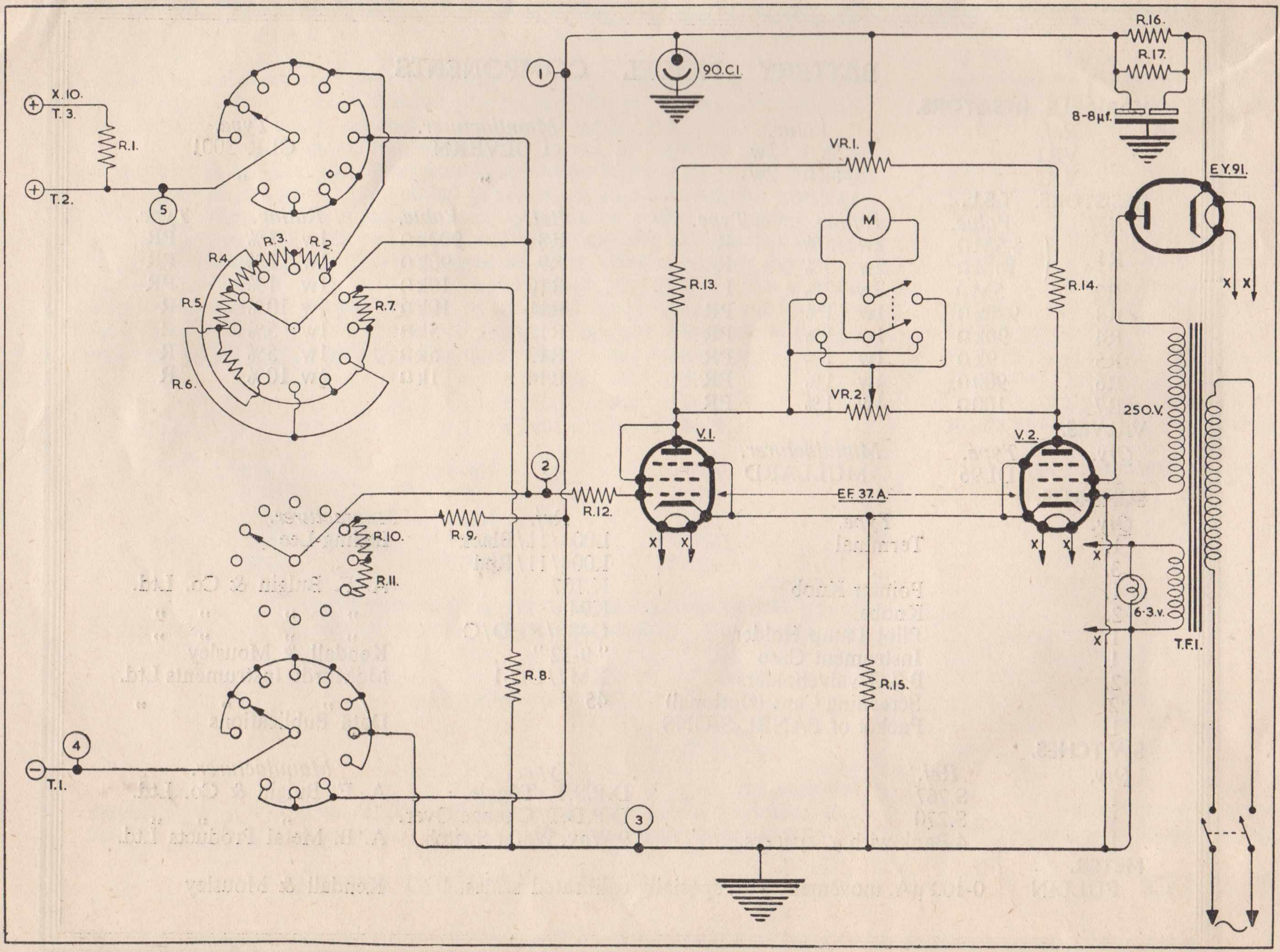


Fig. 10. ·The Mains Model.

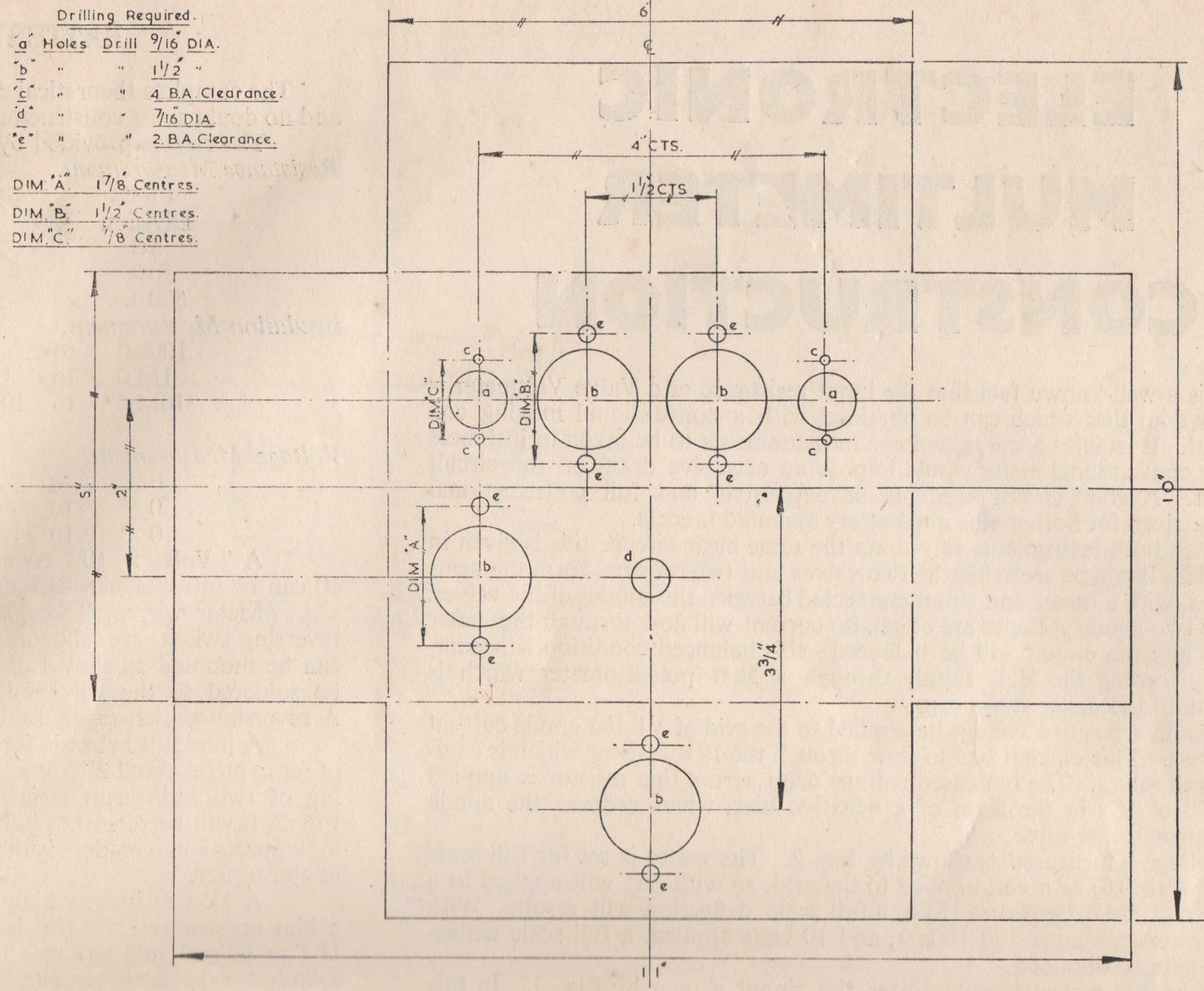


Fig. 11. Chassis Measurements for the Mains Model.

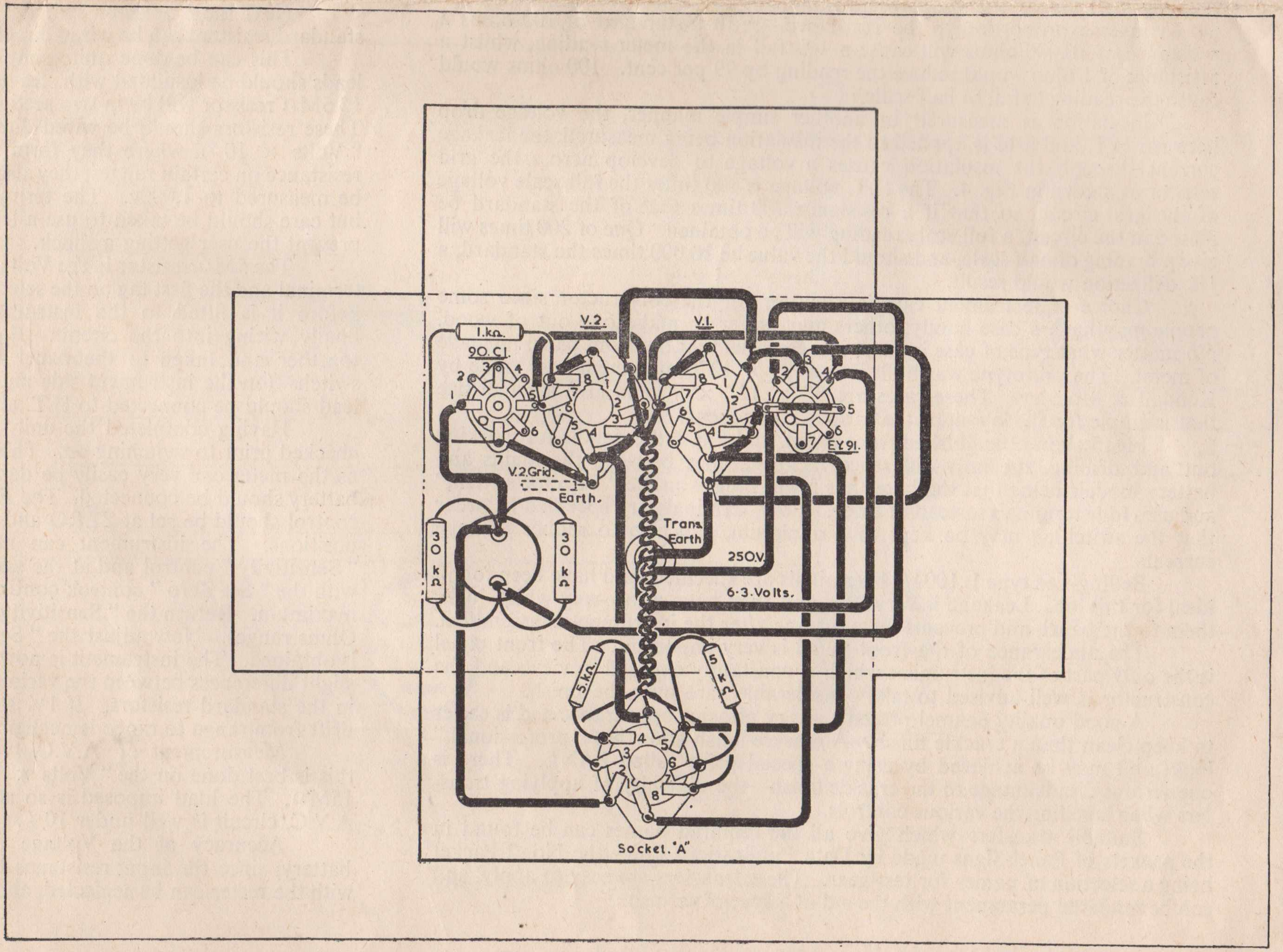


Fig. 12. Under chassis wiring.

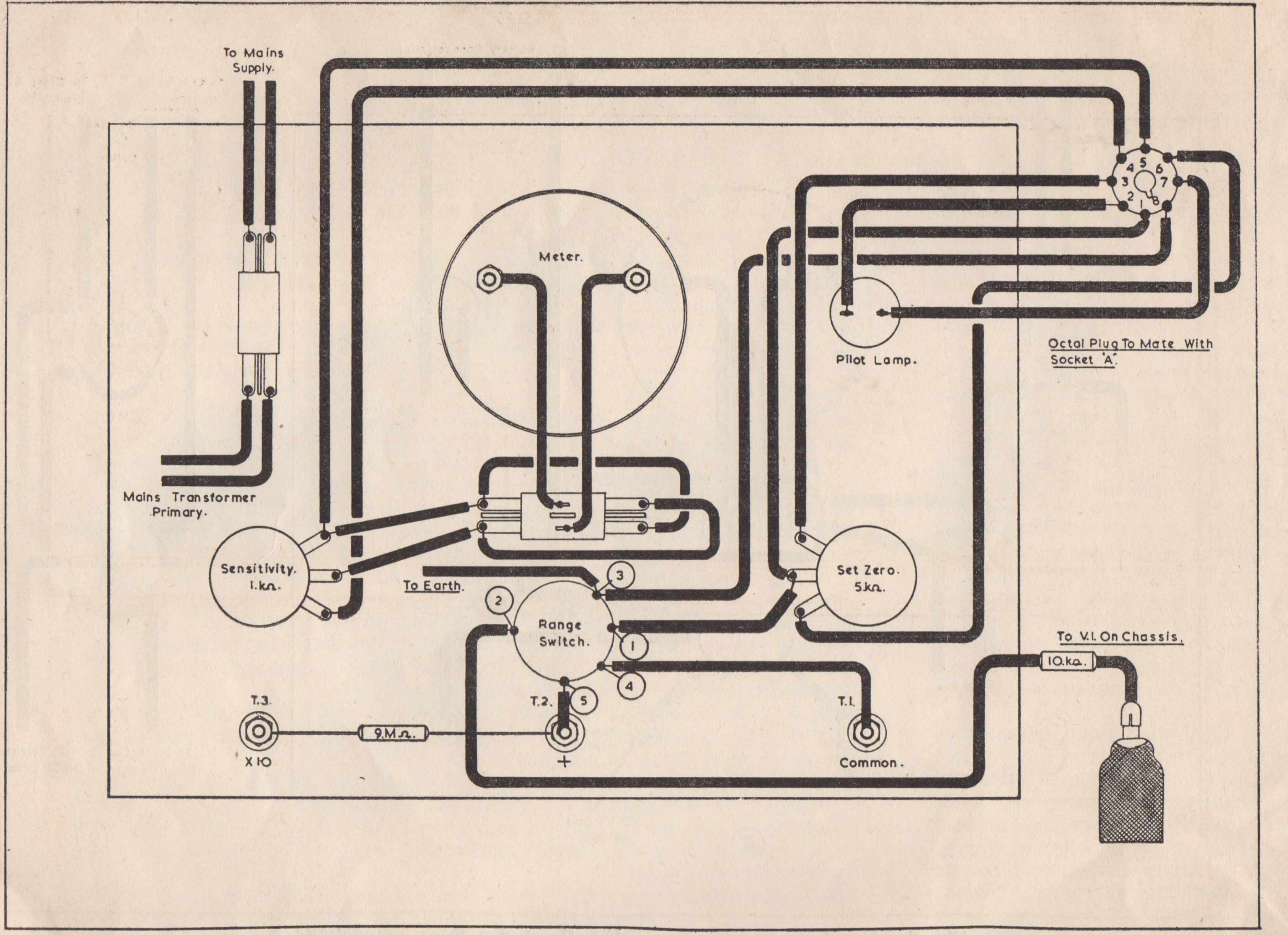


Fig. 13. Mains Model Rear Panel.

BERNARDS RADIO BOOKS

No.		
10.	Manual of Log. and Maths. Tables	1/-
35.	Dictionary of Mathematical Data	2/-
39.	Tool Makers' and Engineers' Manual	1/-
56.	Radio Aerial Handbook	2/6
57.	Ultra-Shortwave Handbook	2/6
58.	Radio Hints Manual	2/6
61.	Amateur Transmitter's Construction Manual	2/6
63.	Radio Calculations Manual	3/6
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82.	AC/DC Receiver Construction Manual	2/6
83.	Radio Instruments and their Construction	2/6
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90.	Wireless Amplifier Manual No. 2	3/-
93.	Power Pack Manual	4/6
94.	Practical Circuits Manual	3/6
96.	Crystal Set Construction	1/-
97.	Practical Radio for Beginners, Book 1	3/-
99.	One Valve Receivers	1/6
100.	A Comprehensive Radio Valve Guide, Book 1	5/-
101	Two Valve Receivers	1/6
102.	40 Circuits Using Germanium Diodes	3/-
103.	"Radiofolder" A. The Master Colour Code Index for Radio and Television	1/6
104.	Three Valve Receivers	1/6
106.	Radio Circuits Handbook No. 4	2/6
109.	High Fidelity Radio ; Design and Construction by N. Bonavia Hunt	3/6
110.	The Emperor : A Radio-gram for Home Constructors	3/6
111.	"Radiofolder" B. A Practical Oscilloscope	2/6
114.	"Radiofolder" E. An Inexpensive Tape Recorder	2/6
115.	Constructors' Handbook of Germanium Circuits	2/6
117.	The Tele-King : Constructional Envelope	6/-
118.	Practical Coil Construction for Radio and Television	3/-
119.	The Practical Superheterodyne Manual	3/-
120.	Radio and Television Pocket Book	2/6
121.	A Comprehensive Radio Valve Guide, Book 2	5/-
122.	Wide Angle Conversion : for Home Constructed Televisors : Constructional Envelope	3/6
123.	"Radiofolder" F. The Beginners' Push-Pull Amplifier	1/6
124.	"At a Glance" Valve and Tube Equivalents for Radio and Television	5/-
125.	Listeners' Guide to Radio and Television Stations of the World	2/6
126.	The Boy's Book of Crystal Sets	2/6
127.	Wireless Amplifier Manual No. 3	3/6
128.	Practical Transistors and Transistor Circuits	3/6
129.	Universal Gram-Motor Speed Indicator	1/-
	A Magnetic Tape Recorder	3/6
	The Electronic Photographic Speedlamp : How to Make It and How to Use It	3/6
	Universal Valve Guide	15/-
	International Radio Tube Encyclopaedia, 1954 Edition	42/-