AUTOBALANCE UNIVERSAL BRIDGE

B641

MAINTENANCE MANUAL

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INTRODUCTION

1 The physical description, specification and use of this instrument are dealt with in the Operating Instructions supplied with the instrument. This manual has been prepared for the benefit of those users who require a more detailed knowledge of the circuits used, their operation and adjustment.

2 The first section is a functional description of the complete instrument. This gives a brief summary of the basic bridge system and is followed by an expanded description of the part played by each circuit in the instrument. This description is related to a block diagram.

3 The second section gives a detailed description of the individual units contained in the instrument. Well-known circuits are not described in detail, since such circuits are analysed in most standard text books on electronics. Although the complete circuit diagram of the instrument is bound at the end of the book, the text describing individual units is accompanied by the relevant part of the circuit diagram simplified where necessary to aid its comprehension.

4 The third section contains complete instructions for the adjustment of preset controls and the replacement of digital indicator tubes and panel lamps. In preparing these instructions the use of any special test equipment has been avoided. Finally, a complete list of electronic components is given.

5 The Autobalance Universal Bridge B641 uses the transformer ratio-arm principle. A complete analysis of this type of bridge is given in the Wayne Kerr Monograph No. 1, 'The Transformer Ratio-Arm Bridge'. An analysis of the self-balancing principles used in this instrument is given in Electronic Engineering Vol. 35, No. 430, December 1963, 'Self-Balancing Transformer Ratio-Arm Bridges'. Copies of the Monograph and reprints of the article are available on request.

FUNCTIONAL DESCRIPTION

Summary

6 The instrument comprises a transformer ratio-arm bridge fed from a 1592Hz oscillator, an error amplifier, a 90° phase-shifter, a base drive amplifier and two phase-sensitive detectors - one for capacitance and the other for conductance. For normal measurements ~~(Range 2 onwards)~~ these elements are arranged as shown in the block diagram Fig. 1. Low impedance measurements are treated as a special case and described in paragraphs 17 and 18.

7 A standard voltage derived from a Wien Bridge oscillator* is applied to the component under test, and the resulting current is fed via a current transformer to the error amplifier. A current from the error amplifier output is fed back to oppose the original current. Ideally, the system would balance when these currents were exactly equal. However, since this would remove the error amplifier input signal, the balance falls short of the ideal condition by an amount which can be predetermined according to the required accuracy of the bridge. The approach to the ideal condition is governed only by the gain of the error amplifier, which can be made as large as necessary.

8 It can be shown that the error amplifier output has components that are directly proportional to the capacitance and conductance of the component under test or, as the decades are brought into circuit, they are proportional to the difference between the decade setting and the value of the test component. These components are then separated to operate the C and G meters simultaneously.

The Bridge

9 Referring to Fig. 1, the voltage transformer T1 has a winding, tapped at 1, 10, 100 and 1000 turns, which produces a voltage E_u. This voltage is applied to one side of the unknown, Y_u, and causes a current I_u to flow through Y_u to a winding on the current transformer

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* Early models of B641 were fitted with a thermistor bridge oscillator - see Appendix 1.

T2. This winding is also tapped at 1, 10, 100 and 1000 turns, the tap on this, and also that on T1, being selected by means of the Range switch.

10 The flux in T2 causes an input signal to be fed to the error amplifier; a current, I_f, proportional to the amplifier output is fed back to N_f turns on T2 where it opposes the original current. Since, at this stage in the measurement, the decades are not in use, the net flux in T2 is that produced by the difference between I_u and I_f (the feedback current) at the end of the preliminary balance (i. e. before introducing the decades). The gain of the error amplifier is such that this flux can be assumed to be zero. There is therefore no voltage across the transformer windings and, consequently, E_u appears across Y_u.

11 The error amplifier output has in-phase and quadrature components that are respectively proportional to the conductance and capacitance of the test component. This signal is fed directly to the phase-sensitive detector associated with the conductance meter. The signal is fed to a 90° phase-shifter whose closed loop gain is unity. The output from this circuit is taken to the phase-sensitive detector associated with the C meter. This arrangement gives an aperiodic indication of capacitance and thus does not rely upon the oscillator frequency for accuracy.

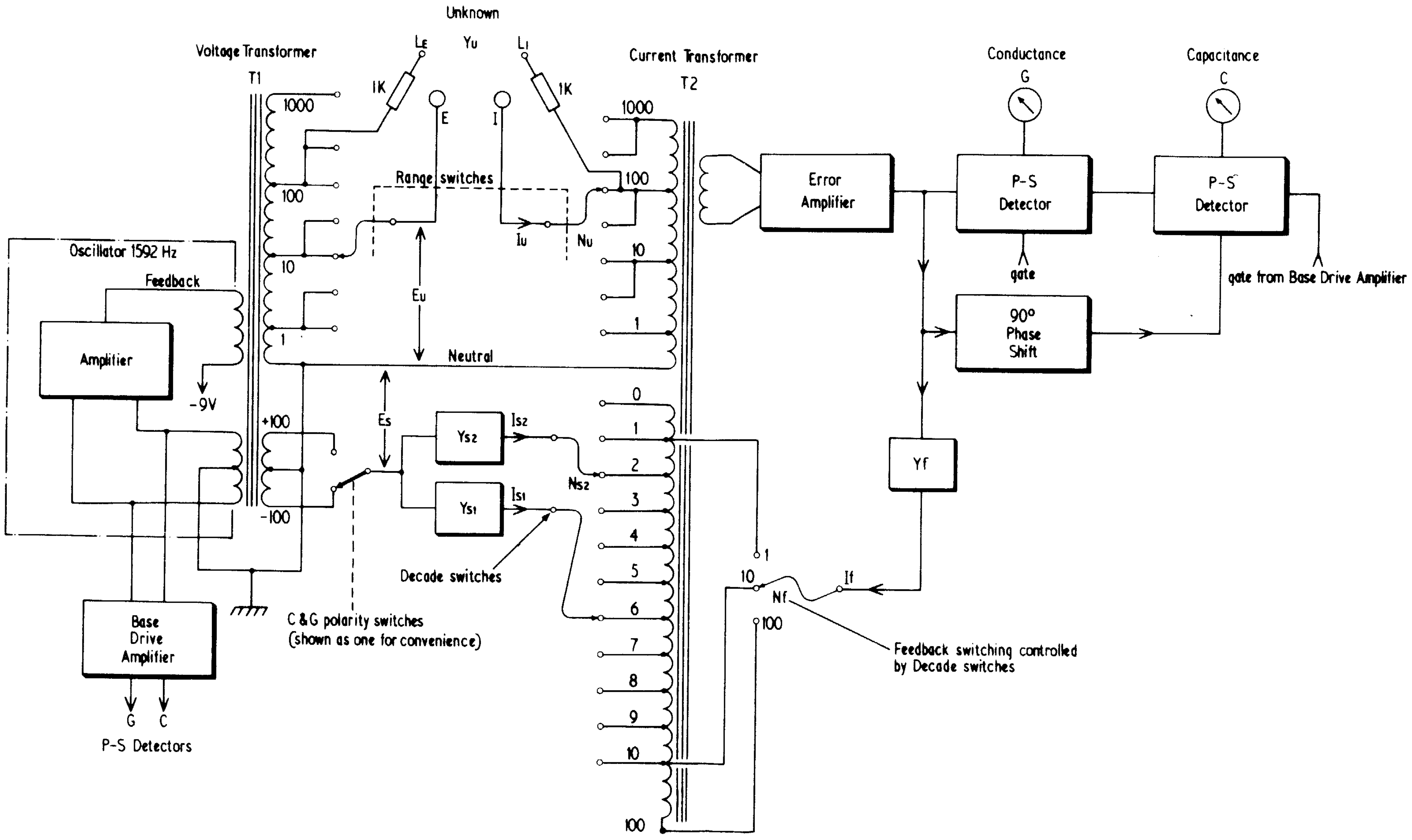
12 Both detectors have a reference signal which is derived from the oscillator via a winding on the voltage transformer. Because the reference signal has a sinusoidal waveform it is not suitable as a switching waveform, but is used instead to drive a square wave generator. This circuit is referred to as the Base Drive Amplifier because of its application; it has four outputs, one for each transistor in the two phase-sensitive detectors. The detectors operate the C and G meters via the appropriate polarity switches.

13 The voltage transformer T1 has another winding consisting of 200 turns centre-tapped. This provides the voltage E_s, which is applied to the bridge standards. The centre-tap is connected to neutral so that E_s can be either positive or negative as required. The voltage E_s is applied to the capacitance and conductance standards Y_{s1} and

Y_{s2} (Fig. 1) to produce the currents I_{s1} and I_{s2}. Another winding on the current transformer T2 is tapped at ten equi-spaced points; this is the decade winding to which the currents I_{s1} and I_{s2} are fed. In the main circuit diagram, Fig. 13, the capacitance standards are C12 trimmed by C67 and C11(major decade), and C14 trimmed by C13(minor decade). The conductance standards are R112 plus R46 (major) and R113 plus R45 (minor).

14 Whilst looking at the main circuit diagram, it is convenient to discuss some other details of the bridge circuit. The initial capacitance trimming of the bridge is effected by feeding current from the -100 turn tap of T1 through the trimmer capacitor C10 to the +100 turn tap of T2. To make C10 effectively cover zero, and to allow for its residual capacitance at minimum setting, current is fed in the opposite sense, via C66, from the +100 turn tap of T1. Conductance is trimmed by feeding current via RV2 and R120 to the current transformer T2; in this case, zero is covered by connecting RV2 between +10 and -100 turns on T1. Capacitor C9, connected between the E terminal and a single turn on T2, balances out residual capacitive currents introduced into T2 by the stray capacitance of the Range Switch.

15 While the decades are not in use, the error amplifier feedback current is fed to the 100-turn tap on T2 and so the amplifier is at its lowest sensitivity. When the first digit of either the C or the G meter indication is transferred to the appropriate decade, I_{s1} (or I_{s2}) replaces a part of I_f and so would back off the meter by that amount. However, at the same instant, the release of the reset button causes the feedback current to be transferred to the 10-turn tap, thereby increasing the error amplifier gain by 20dB. Thus, the error amplifier and meter circuits now deal with the second and lower significant figures. Similarly, when the minor decades are brought into use, the feedback connection is transferred to the 1-turn tap on T2 and the amplifier sensitivity is increased by a further 20dB.



Block Schematic-B641 Fig 1.

16 Three other facilities are associated with the bridge proper, namely, the external standard connections, the calibrated offset or vernier controls and the external source and detector facility; their use is fully dealt with in the Operating Instructions. The -10 and -100 turn taps on the standard winding of the voltage transformer, and the +10 and +100 turn taps on the current transformer are brought out to front-panel connectors. Current from the plus or minus 100-turn tap on the voltage transformer is fed to the sliders of the vernier controls and thence to the +10 turn tap on the current transformer. Thus, each potentiometer gives a continuous control equivalent to one unit of the appropriate minor decade. The switch SD has wafers that

(a) connect the external source input at SKT9 to T1 primary

(b) connect T2 secondary to the external detector at SKT10

(c) disconnect the error amplifier output from T2.

17 When it is required to measure impedance values below 10Ω, the method of measurement described in the previous paragraphs becomes impracticable owing to the uncertainty of lead and contact resistance. For the precise measurement of such low impedances a difference technique is adopted.

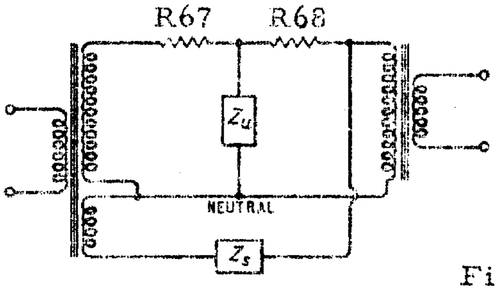


Fig. 2.

18 In the bridge arrangement as previously considered, a standard voltage is applied to the unknown and the resulting current is compared with that in a standard impedance. For low values of unknown impedance (i. e. when the Low Impedance sockets are used in conjunction with Range 1), the bridge is rearranged so that Z_u is the shunt element in a T-network (see Fig. 2). If the series

elements (R67 and R68) are made sufficiently large (100 times) compared with the unknown, the source side of the bridge can be considered as a constant current generator while the detector side functions as a voltmeter. This technique is analysed in Wayne Kerr Monograph No. 1.

CIRCUIT DESCRIPTION

Oscillator

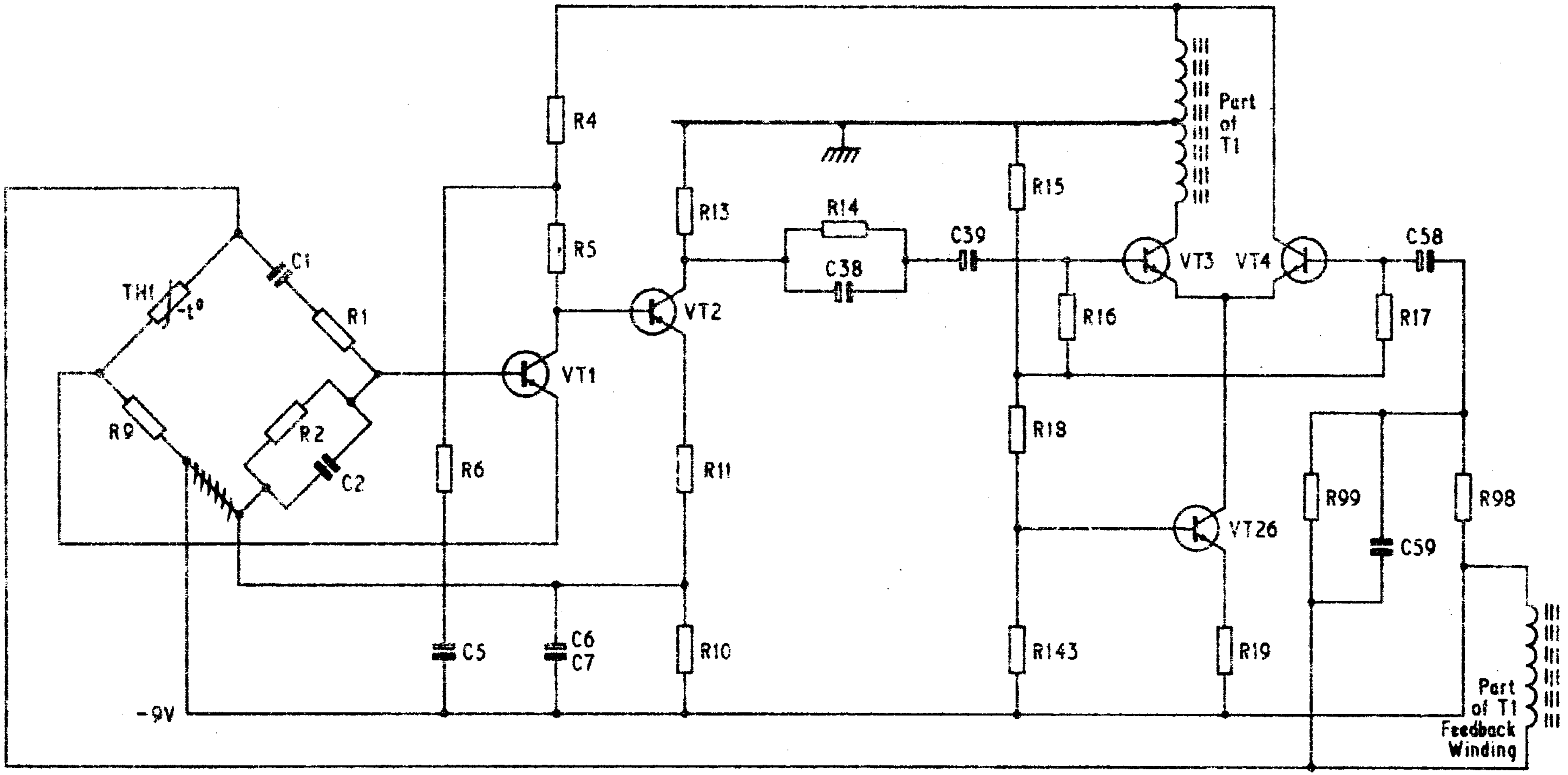
19 A simplified circuit diagram of the oscillator is given in Fig. 3. The circuit is essentially that of a Wien Bridge oscillator in which the four arms of the bridge network are R1/C1, R2/C2, thermistor TH1 and silistor R9. Overall feedback is taken from the feedback winding on T1 and the parameters of the Wien bridge network are such that the feedback is in phase at 1592Hz so causing the circuit to oscillate at that frequency.

20 Transistors VT1 and VT2, which form the high gain amplifier, are connected as a d. c. feedback pair to give improved stability over the operating temperature range. Transistors VT3 and VT4 are a long-tailed pair output stage. The emitter circuit of the long-tailed pair incorporates a constant current generator, VT26.

21 Initially, the collector of VT1 and the base of VT2 are at chassis potential and VT2 conducts. The potential at the emitter of VT2 is divided by the potential divider R10/R11. The voltage at the junction of R10/R11 is fed back via R2 to the base of VT1, so causing VT1 to conduct. VT2 base and, hence, emitter potential is reduced and this, in turn, reduces the potential at VT1 base. Negative feedback, moderated by R6/C5, is applied to VT1 collector circuit by returning R4 to the collector of VT4.

22 The system is stabilised at a level determined by the feedback tapping point on VT2 emitter. The d. c. feedback to VT1 base greatly reduces the tendency of the base/emitter potential to drift with temperature variation; this ensures that the operating point for VT2 collector is reasonably constant. Capacitors C6/C7 prevent feedback at the operating frequency.

R	9 2 1 6 4 5 13 11 10 14 15 18 143 16 19 99 17 98	R
C	1 2 5 6 7 38 39 58 59	C
Misc.	TH1 VT1 VT2 VT3 T1 VT26 VT4	Misc.



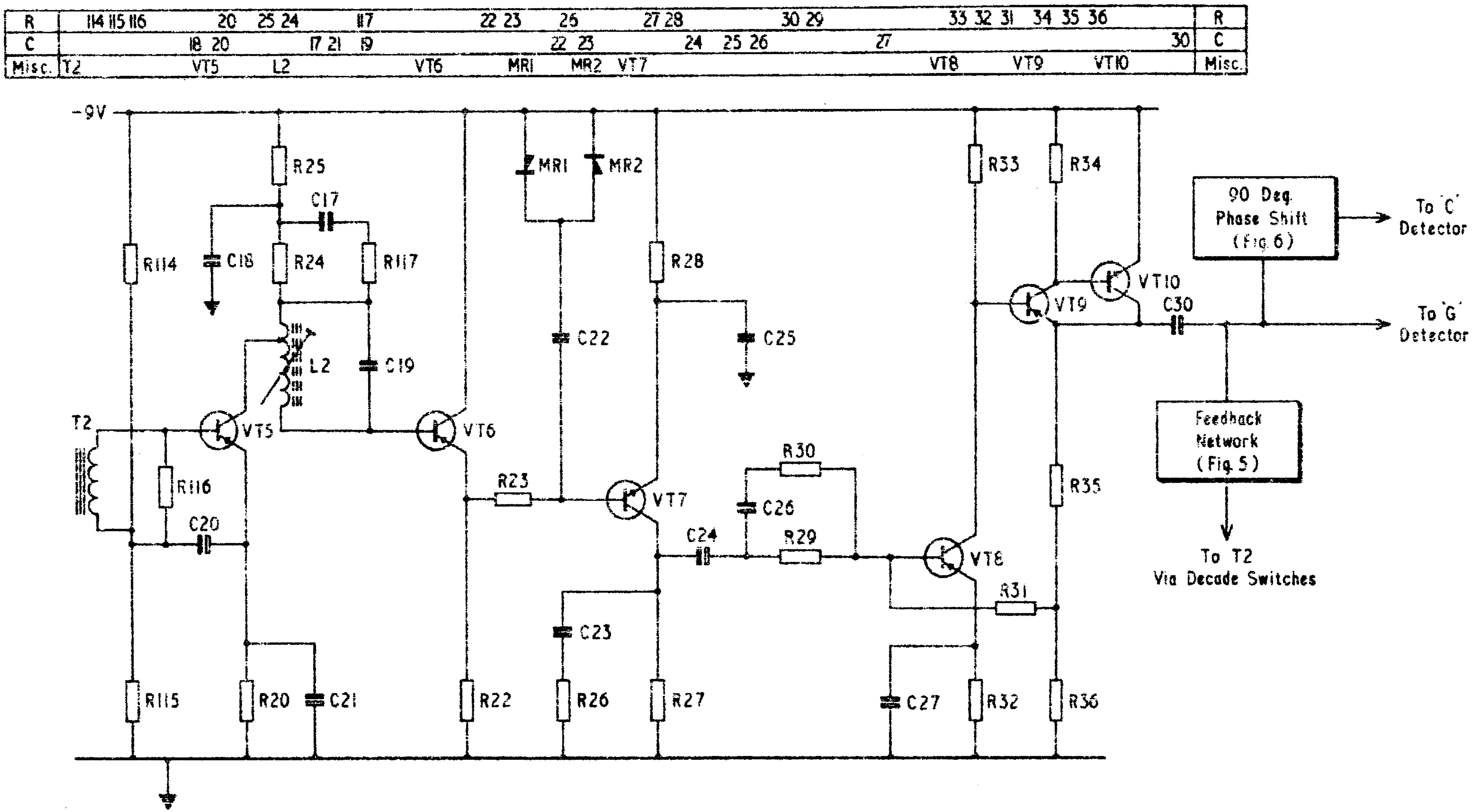
23 The output from the d. c. feedback pair is taken from the collector of VT2 via the phase-correcting coupling network R14, C38, C39 to the oscillator output stage. This comprises the long-tailed pair VT3 and VT4 in whose collector circuit is the centre-tapped primary winding of the voltage transformer T1. The transistor VT26 in the emitter circuit of VT3/VT4 gives the effect of a high impedance without the necessity for a high voltage h. t. line.

Error Amplifier

24 The 250-turn secondary of the current transformer T2 feeds the error signal to the base of VT5, an amplifier stage whose load is the tuned circuit L2/C19 (see Fig. 4). The tap on L2 is so arranged that its Q is not unduly damped by the collector impedance of VT5. The network comprising R24, C17 and R117 forms part of an overall scheme to ensure that the response falls to unity open loop gain at the rate of 10dB per octave. The emitter follower VT6 acts as a buffer between the tuned circuit and the following amplifier VT7. The diodes MR1 and MR2 limit the signal amplitude at the input to VT7 and thus prevent phase rotation, which would otherwise occur under overload conditions. Further amplification takes place in VT7, in whose collector circuit C23 and R26 form another part of the overall response control.

25 Transistors VT8, VT9 and VT10 comprise an operational amplifier whose gain is determined by the potential divider R35/R36, by the feedback resistor R31 and the input network R29, R30 and C26. The input network gives a rising characteristic at low frequencies and so helps to overcome the fall caused by the current transformer. The compound emitter follower VT9/VT10 gives a low output impedance from which is fed the phase sensitive detectors and the main feedback elements. The feedback resistor R31 stabilises the operating point of the whole stage in a manner similar to that of the d. c. feedback pair in the oscillator (para. 21 and 22).

26 The error amplifier output is taken through C30 to the bridge feedback circuit (Fig. 5). The switch SD-B3 disconnects the amplifier output



Error Amplifier Fig.4

when an external source and detector are in use. The network R38, R39 and C28 offsets the small capacitive coupling between input and output of the error amplifier, which, if not corrected, would cause phase errors. Potentiometer RV6 (C. ZERO) feeds a portion of the output to C29, thus making the feedback variably capacitive. The C meter indicates zero when RV6 is set to give a capacitive current equal to the inductive current from the T-network R38, C28 and R39. Resistors R37 and R40, in series with the phase adjusting capacitors, limit the phase changes at high frequencies.

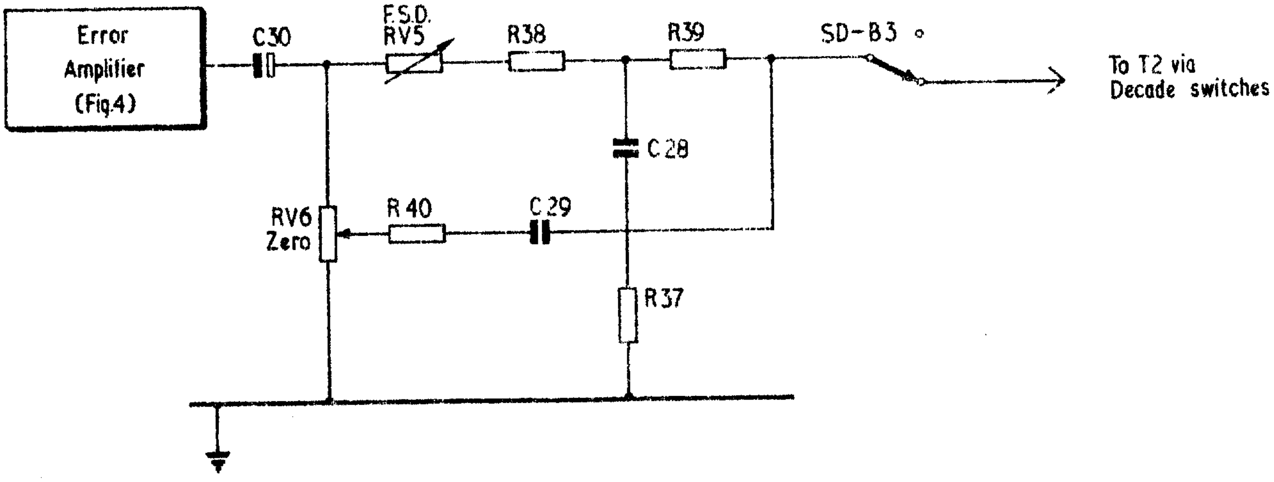


Fig. 5. Main Feedback Network

90° Phase Shift Circuit

27 Since the capacitance component of the error amplifier output is in quadrature with the detector reference signal, the output must be fed through a 90° phase shift circuit. This circuit is shown in Fig. 6; VT13 is a conventionally biased voltage gain stage and VT14 is an emitter follower.

28 Input current is fed through R48 to the base of VT13, which can be regarded as a virtual earth. This current is balanced by the feedback through C32 so that the output voltage is in quadrature with the input current. Since the impedance of C32

at 1592Hz is nominally equal to that of R48, the overall closed loop gain is unity. The network comprising RV7 and C31 adjusts the phase change to 90 degrees exactly. The overall nature of the Phase Shifter is that of an integrator, which thus offsets the differential nature of the capacitive current through the unknown. The overall measurement of capacitance is therefore aperiodic and its accuracy is independent of the oscillator frequency.

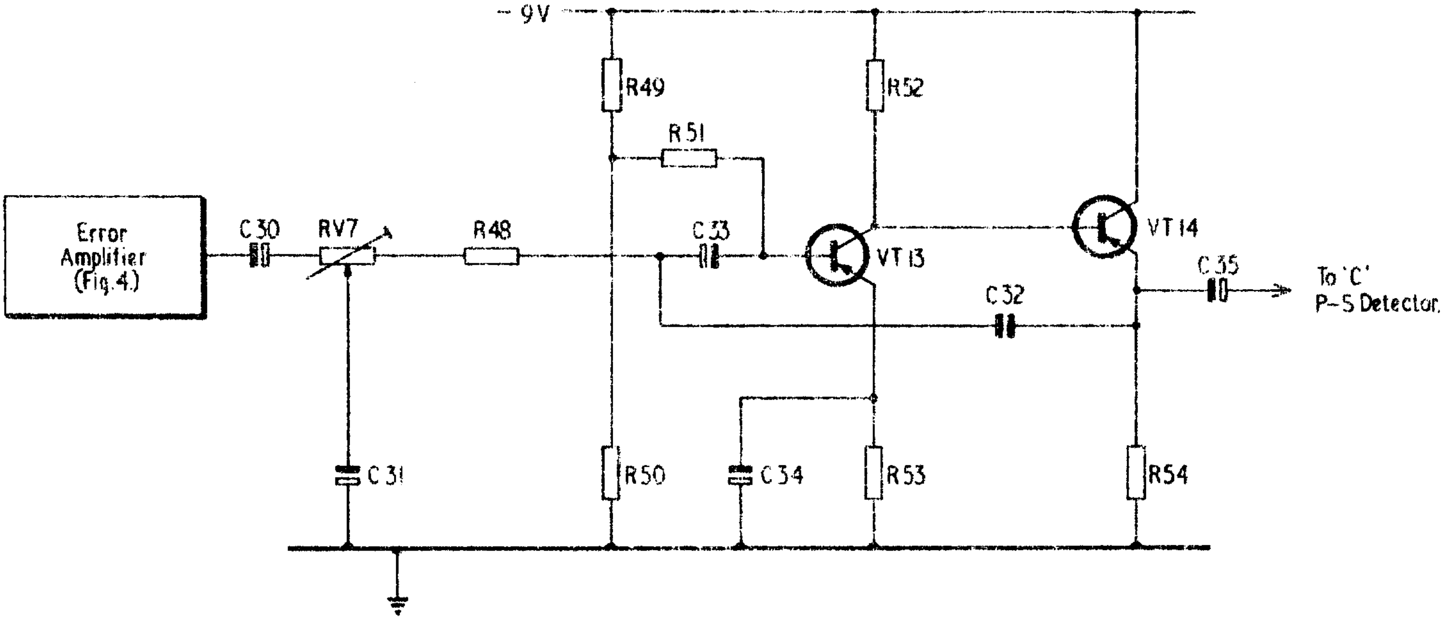


Fig.6. 90° Phase Shift Circuit

Phase Sensitive Detectors

29 The two meters are each operated by identical phase sensitive detectors, VT11/VT12 for conductance and VT15/VT16 for capacitance. A slight difference in the switching of the conductance detector facilitates the use of the G meter for checking the supply voltage. Fig. 7 shows the basic detector circuit with polarity switching and digital output circuits omitted for clarity; since the diagram applies to both C and G circuits, no references are given.

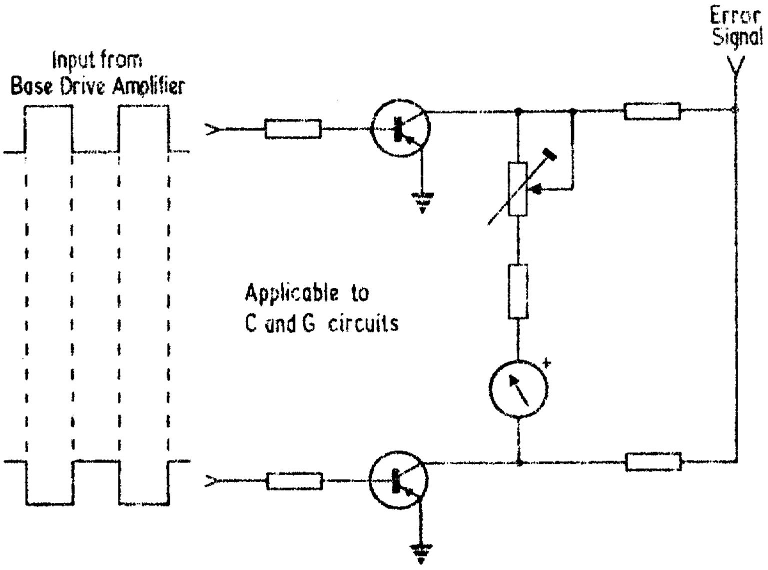


Fig.7 Basic Phase-Sensitive Detector

30 It will be seen from Fig. 7 that the input to the base of each transistor is in phase opposition. The transistors are therefore switched on and off alternately at each half-cycle of the oscillator frequency. Thus the meter, which is connected to the error signal, has its connections effectively reversed at each half-cycle and so the system behaves as a full-wave rectifier.

Base Drive Amplifier

31 The purpose of the Base Drive Amplifier, whose circuit is given in Figure 8, is to provide a fast switching waveform for the base circuits of the two phase-sensitive detectors (see para. 30 and Fig. 7). Transistors VT17 and VT18 form a regenerative switching circuit which is used here to amplify and shape the sinusoidal signal from the 200-turn winding on T1.

Decade Indicators

32 The illuminated display of the values of capacitance and conductance is given by means of digital display tubes, three tubes plus a decimal point indicator for each. The display tubes are energised by means of the push-button decade switches, each decade comprising

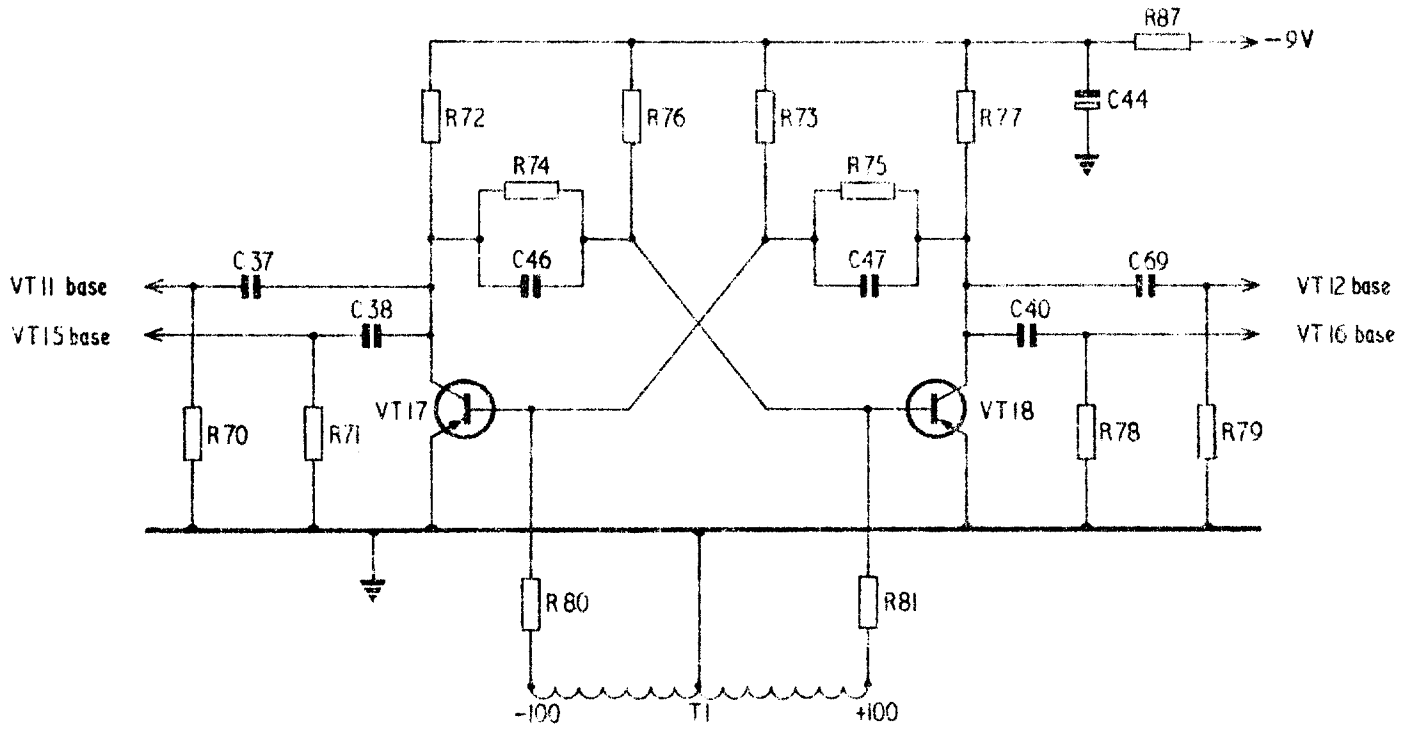


Fig.8. Base Drive Amplifier

eleven numeral buttons (0-10 inclusive) and a reset button. The anode of each display tube is connected through a load resistor to a 250V h. t. supply and the operation of any major or minor decade button between 0 and 9 connects the appropriate cathode to ground (see Fig. 9). The circuit is so arranged that when button 10 on a minor decade is operated, the major display tube indicates a numeral which is greater by one than the operated button on the major decade; at the same time, the minor display tube shows 0 (e. g. if the major button 4 and minor button 10 are operated, the display tubes indicate 5. 0).

33 This is done by means of a second pole on the switch associated with each major decade button. The 'on' position of this second pole is connected to the 'off' position of the first pole associated with the next higher button. The wipers of the second poles 0 to 9 inclusive are connected to the 'on' position of the minor decade button 10. This is clarified in Fig. 9b, which shows the connections for the example in para. 32 when (a) buttons 4. 9 and (b) buttons 4. 10 are pressed.

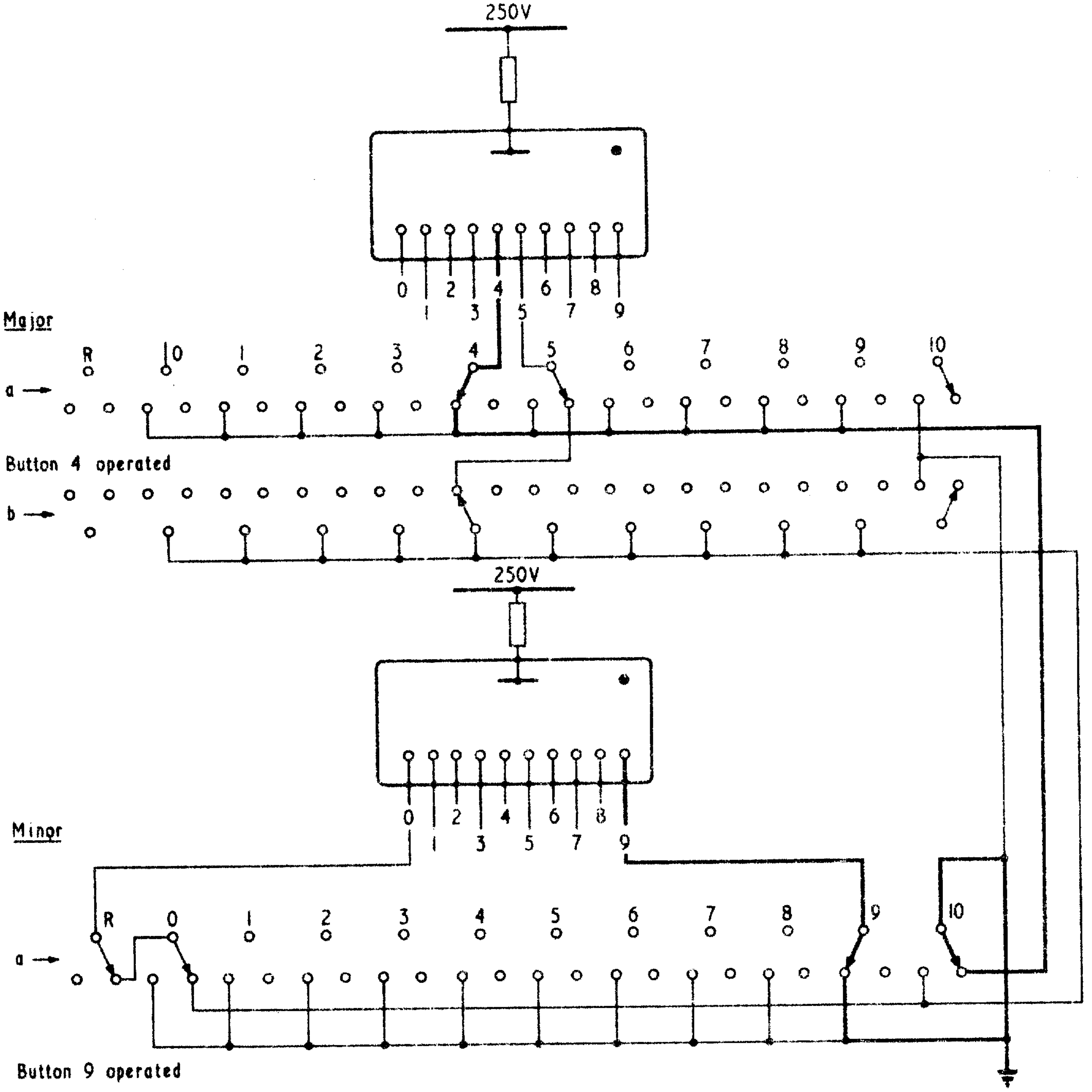


Fig. 9a. Earth return path for display 4·9

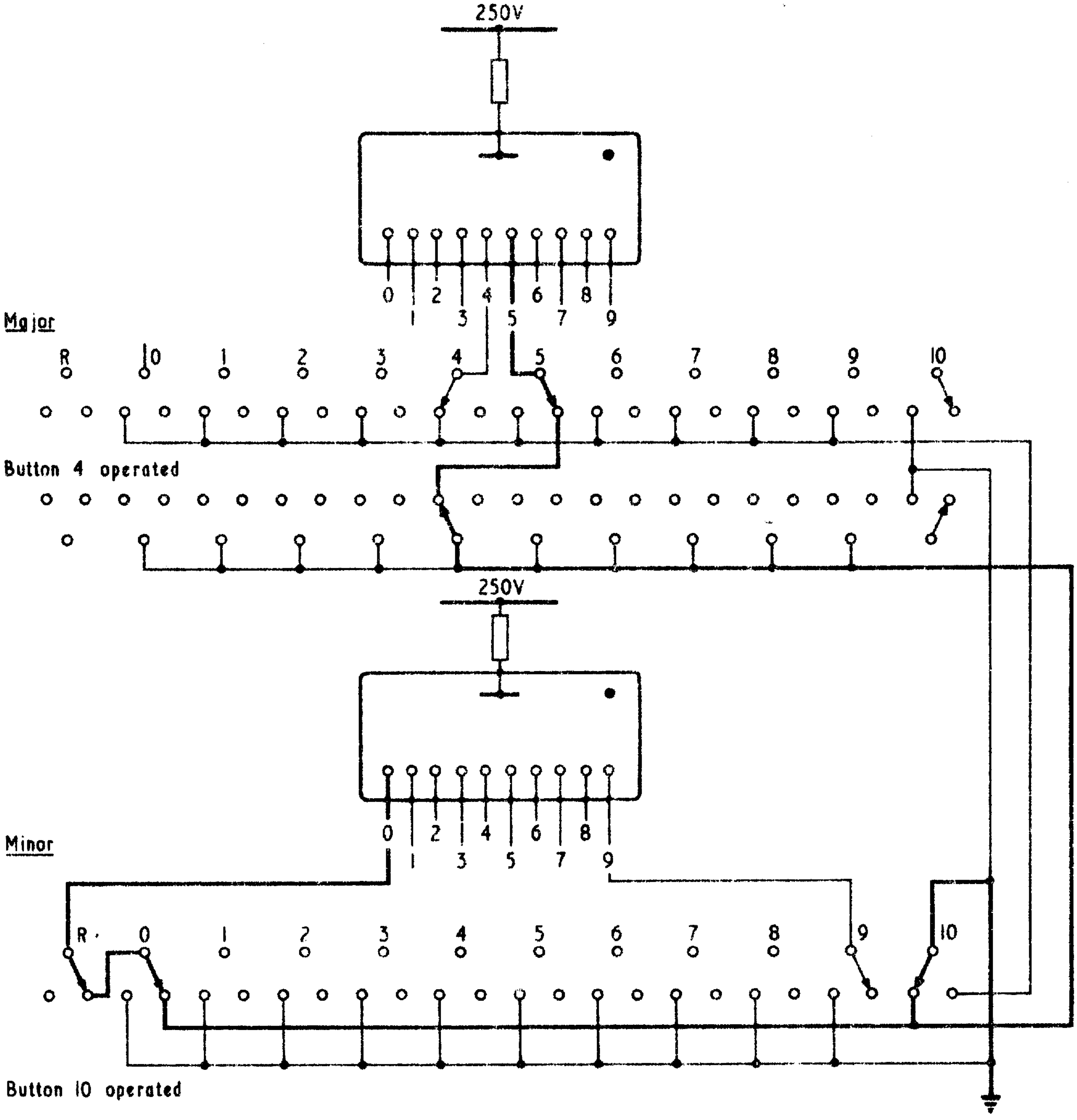


Fig. 9b. Earth return path for display 5·0
when buttons 4·10 are operated

Decade Switching showing Indicator 'Carry' Fig. 9

D. V. M. Output Voltage

34 The circuit shown in Fig. 10 provides a voltage output with respect to ground which is proportional to the meter reading and can be used to operate a digital voltmeter or recorder. The circuit shown is that for capacitance; the circuit for conductance is identical although R82, MR3 and C41 are common to both. Although the meter indicates a steady direct voltage, both sides are approximately balanced about ground and so the meter voltage is not directly suitable as a DVM output.

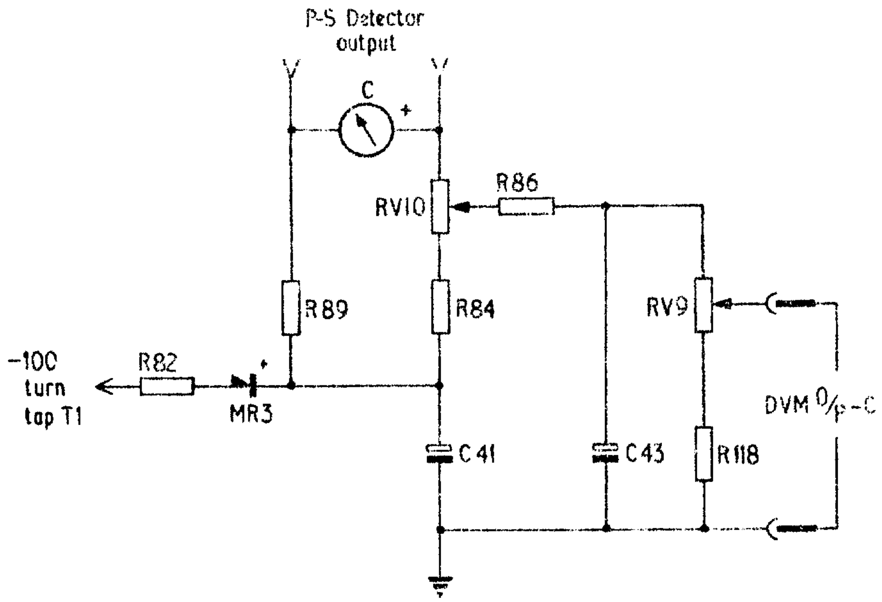


Fig.10. Typical DVM Output Circuit

35 When the p-s. d. transistors are conducting, the associated meter is not connected to ground potential exactly, but to a few millivolts negative with respect to ground. To counteract this, a small voltage is taken from T1, rectified and smoothed by R82, MR3 and C41, and fed via R84 and RV10 to one side of the meter. The correcting voltage is also fed via R89 to the other side of the meter so as to preserve the symmetry of the p-s. d. A voltage is taken from the slider of RV10 and fed via the 1592Hz ripple filter R86/C43 to the potentiometer RV9. Potentiometer RV10 is adjusted to give zero C-DVM output when the C-meter indicates zero; RV9 adjusts the C-DVM output to accommodate various values of load impedance.

BCD Output

36 The BCD output is explained in the Operating Instructions handbook, which also gives a simplified diagram of the associated switching. The complete circuit diagram of the BCD switching is given in Fig. 15 at the end of this manual.

Power Supply Unit

37 The Power Supply Unit provides -9V d.c. with respect to ground for the main bridge circuits; +200V d.c. for the operation of the digital indicator tubes, and finally, 6.3V d.c. to operate the Range lamps. The lamps are operated from a d.c. supply to prevent the injection of 50Hz ripple into the bridge circuits. The operating principles of a series stabilizer circuit are too well known to require elaboration here. The circuit diagram of the Power Supply Unit is given in Fig. 16.

SETTING UP INSTRUCTIONS

38 The following paragraphs give complete instructions for the adjustment of all preset controls in the instrument. Since these adjustments have a considerable bearing on the performance and accuracy of the instrument, it is essential that they should be performed only by skilled operators. Where applicable, simple tests are given to verify correct functioning.

A general view of the rear of the instrument is shown in Fig. 11. This shows the location of the main printed circuit boards. Some operations require the lowering of the p-c boards; this is shown in Fig. 12.

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CAUTION

Although the electronic circuits in general operate from a 9V supply, there is a 200-250V d.c. supply to the digital indicator tubes. Due precautions should be taken when operating on or near these tubes.

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NOTE: The upper decade in both C and G banks is the more significant and is therefore referred to as the major decade. The lower decades are referred to as the minor decades.

Test Equipment Required

39 The following items of test equipment are required to facilitate the setting up procedure.

(i) Audio Signal Generator (e.g. Wayne Kerr type S121)
(ii) Double Beam Oscilloscope
(iii) Waveform Analyser (e.g. Wayne Kerr type A321)
(iv) Digital Voltmeter
(v) Miscellaneous components:

Capacitors : 0.1μF ±10%; 0.01μF ±0.01%
Resistors : 100kΩ ±1%; 10kΩ ±0.01%; 39kΩ ±5%
Variable Resistor : 1kΩ.

Feedback Switching Check

40 The following procedure provides a quick check on the correct functioning of the feedback switching. Set the instrument for normal measurements and press all four reset buttons. Connect a capacitor of value 0.1μF to the unknown sockets. The accuracy of this component is of little importance. Select Range 3 and note that the C meter indicates approximately 10. If the indication is off scale, adjust the F.S.D. control until the C meter indicates 10. Press the Range 2 button and check that the meter indication falls to 1. Press the 0 button of the C major decade; the C meter indication should return to 10. Press the C major reset and the G major 0 buttons; the C meter indication should remain at 10. Press the Range 1 button; the C meter should indicate 1. Press the C minor 0 button; the C meter should indicate 10. Press the C minor reset and G minor 0 buttons; the meter indication should remain at 10. Disconnect the 0.1μF capacitor.

NOTE: For all the following operations, the rear cover must be removed from the instrument. The cover is held in place by means of four spring fasteners which can be released by a quarter-turn counter-clockwise.

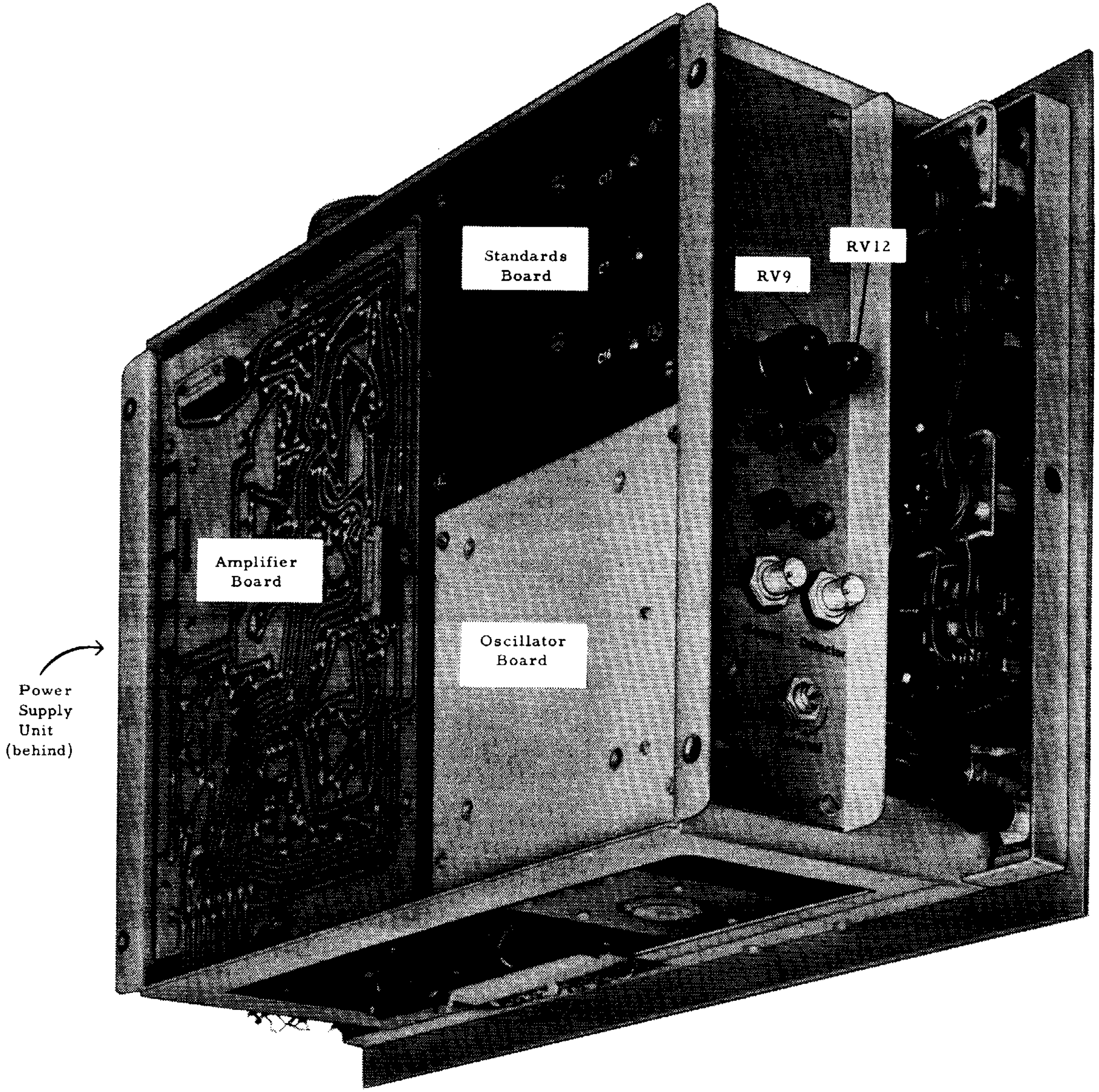

Fig. 11. Rear View with Cover Removed

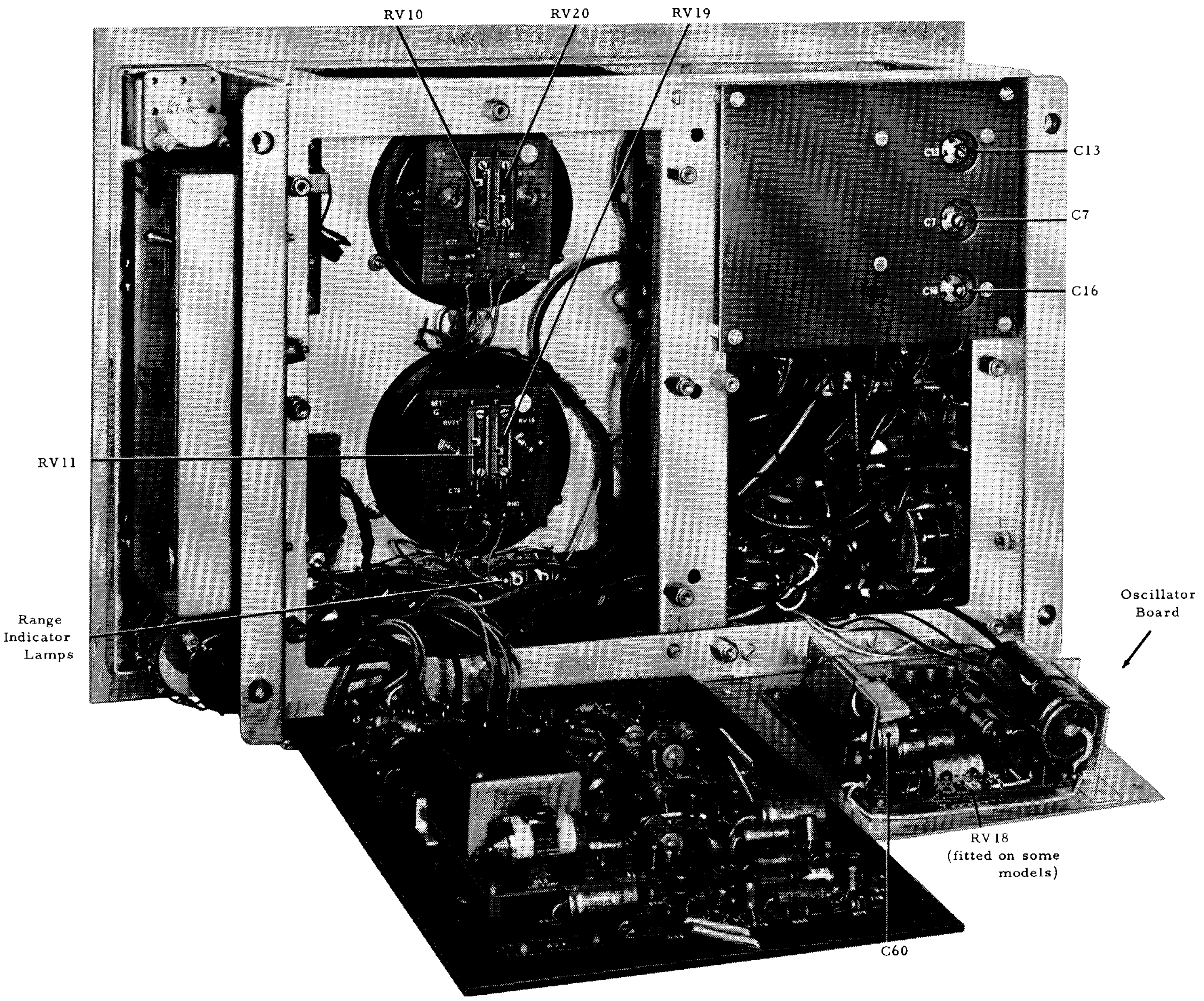

Fig. 12a. P-C. Boards Lowered for Setting-up

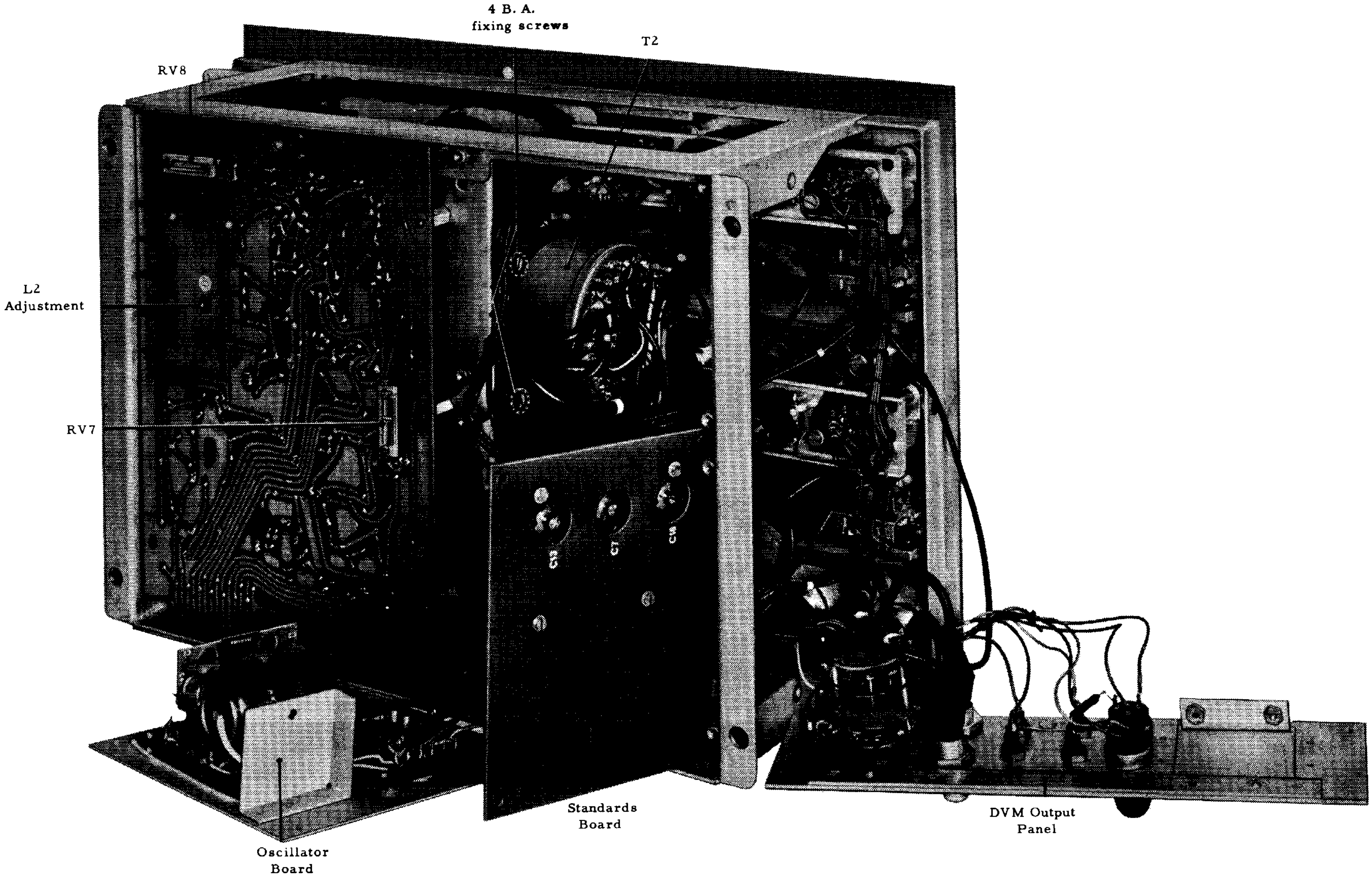

Fig. 12b. P-C Boards Lowered for Setting-up

Oscillator Frequency

41 Connect an oscilloscope to the E-10 socket on the front panel. Using an external audio oscillator, set to 1592Hz, as a reference, adjust C60* on the oscillator P-C board for a stationary 1:1 Lissajous figure.

Amplifier Tuning

42 Remove the eight 6B. A. screws that secure the amplifier P-C board and lower the board to the bench. Disconnect the feedback by removing the screened lead from pin 10 on the amplifier board. Temporarily refit the board. Set the instrument controls to Operate, Range 1, C and G polarity to +, both Vernier controls to zero and all decade 0 buttons engaged. Connect the unknown neutrals together. Carefully adjust the C and G Trim controls for zero meter indication (note that the controls will interact strongly in the absence of feedback).

43 Connect one beam of a double-beam oscilloscope to the E-10 socket and the second beam to the amplifier output at pin 14 on the amplifier board. Connect a 1kΩ potentiometer between the inner and neutral of the unknown E socket; connect a resistor of 39kΩ between the wiper and the unknown I socket. Adjust the potentiometer to give an amplifier output of approximately 1.5V peak-to-peak.

44 Adjust the tuning slug of L2 for maximum amplifier output. Check that the output is exactly in phase with the reference signal from E-10. If there is any discrepancy between the points of maximum amplitude and minimum phase shift, set the slug for zero phase shift. Disconnect the potentiometer and resistors, reconnect the amplifier feedback and secure the P-C board in place.

Setting up the Calibration Controls

45 Set the instrument controls to Calibrate, Range 1, C and G polarity to +, Vernier controls to zero and all decade 0 buttons pressed. Adjust the Trim C and Trim G controls for zero meter indication. Press the 1 button on the C minor decade and adjust the F. S. D.

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* On some models, frequency adjustment is by means of RV18, C60 not being fitted. Other models may have C61 in parallel with C1; if changed C61 must not exceed 100pF, this value giving a frequency change of 5Hz and pro rata.

control until the C meter indicates 10. Adjust the Zero control until the G meter indicates 0; re-adjust the F. S. D. control if necessary [This is NOT the usual 'Calibrate' procedure].

Press the 0 button on the C minor decade and the 1 button on the G minor decade. Adjust the potentiometer RV7 (on the amplifier P-C board) until the C meter indicates zero. Adjust potentiometer RV8 until the G meter indicates 10. Repeat this procedure, making further adjustments as necessary.

Setting Up the D. V. M. and Meter Circuits

46 Connect the digital voltmeter to the C-DVM output sockets. Set the B641 controls to Calibrate, Range 1, all decade 0 buttons pressed and Vernier controls to zero. Adjust the potentiometer RV10 (on the C meter P-C board) until the D. V. M. indicates zero. Press the 1 button on the C minor decade. If necessary, adjust either the F. S. D. or the C Vernier control so that the C meter indicates 10.

47 Set potentiometer RV9 (Set FSD. DVM-C) to its maximum clockwise position. Connect a resistor of value 100kΩ ±1% across the D. V. M. Adjust RV20 until the D. V. M. indicates approximately 105mV. Disconnect the 100kΩ resistor, turn RV9 fully counter-clockwise and check that the D. V. M. indication is less than 100mV. Make small adjustments to RV20 until a setting is found at which the maximum output (RV9 clockwise) into the 100kΩ load is as much above 100mV as the minimum output into no load is below 100mV.

48 The procedure for setting up the G-DVM output is the same as that described above except that for RV9 read RV12, for RV10 read RV11 and for RV20 read RV19.

Neutralizing Stray Capacitance of Range Switch

49 Set the instrument to Calibrate, Range 1, all decade buttons pressed and Vernier controls to zero; remove any connecting leads from the Unknown terminals. Carefully adjust both trim controls for zero indication on their respective meters. Set the function switch to Operate and select Range 7. If the C meter indication has moved

from zero, adjust trimmer capacitor C9 (on the Range switch) to correct the meter indication (i. e., return it to zero).

Setting Up the Standards

50 C Standards Ensure that the instrument is correctly calibrated as described in the previous paragraph. Set the Function switch to Operate, select Range 2 and press all the decade 0 buttons. Adjust the C and G trim controls carefully for zero indication on both meters. Connect a capacitor of value 0.01µF ±0.01% to the Unknown sockets.

51 Set the Vernier C control to 10 (maximum clockwise). Adjust Trimmer capacitor C16 (on the Standards board) until the C meter indicates 0. Disconnect one side of the 0.1µF capacitor. Set the Vernier C control to 0, select Range 4 and check the C and G trim. Reconnect the 0.01µF capacitor, press button 10 on the C major decade and the 0 button on all other decades. Adjust the trimmer capacitor C7 until the C meter indicates 0 exactly. If the meter indication is greater than 0 when C7 is at maximum capacity, the value of C11 must be increased. Set C7 approximately to its mid-position; the meter indication (assuming F. S. D. to be equivalent to 100pF) is then the value in pF by which C11 must be increased. Readjust the trimmer C7 until the meter indication is 0.

52 Press the 9 button on the C major, and the 10 button on the C minor decades. Adjust trimmer C13 until the meter indicates 0. Press the 9 button on the C minor decade and turn the C Vernier to 10. Adjust trimmer C16 until the meter indicates 0.

53 G Standards The conductance standards are trimmed by means of fixed resistors whose values are determined during manufacture, therefore they will not require attention unless the conductance standards themselves are replaced. The trim resistors are R45 for the G minor decade, R46 for G major and R47 for G Vernier. The method by which their values are determined is outlined in the following paragraphs.

54 With the instrument set to Operate and Range 4, carefully check the calibration and trim. Connect a resistor of value 10kΩ ±0.01%

(conductance of 100μMho) to the Unknown sockets. Press button 10 on the G major decade. The amount by which the meter indication departs from 0 represents the required value of R46 (taking F. S. D. as 100Ω). Since the deviation (if any) is invariably negative, the value can be determined as follows: adjust Trim G until the meter indicates 0, then disconnect the 10kΩ resistor, press the G major 0 button and read the now positive meter indication.

55 Reconnect the 10kΩ resistor and press the G major 9 and the G minor 10 buttons. The meter indication - determined as in para. 54 - is the required value for R45 (where F. S. D. is equivalent to 10kΩ).

56 Press the G major 9 and G minor 9 buttons; set the G Vernier to 10. The meter indication - determined as in para. 54 - is the required value for R47 (f. s. d. in this case being equivalent to 1MΩ).

REPLACEMENT OF INDICATOR TUBES

57 Upper Row (C) Indicators

1. Release the four quick-release fasteners on the rear panel and remove the cover.
2. Remove the two 2B. A. screws that secure the indicator tube mounting bracket. Gently move the bracket towards the rear of the instrument.
3. Renew the indicator tubes as necessary, transferring the moulded hood from the old to the new tube. Ensure that the hood is firmly seated on the new tube before replacing the bracket.
4. Secure the tube mounting bracket and replace the cover.

58 Lower Row (G) Indicators

1. Remove the instrument cover as above.
2. Withdraw all plugs from both side panels.
3. Remove the four 2B. A. Allen screws that secure the front handles (two screws per handle); these are accessible when the side doors are open. Remove the handles.
4. Carefully withdraw the chassis through the front of the case framework. In doing this, do not take the weight of the instrument on the top or bottom rails of the front panel as these are not secured

after approximately 1/4-inch of forward movement of the instrument out of the frame.

5. Remove the four 4B. A. screws that secure the DVM output panel and carefully lower this panel to the bench; this is possible without disconnecting any of the wiring.
6. Remove the four 6B. A. screws that secure the oscillator P-C Board (lower right-hand panel as viewed from the rear) and lower this panel to the bench.
7. Remove the four 6B. A. screws that secure the Standards Board (with its attached sub-panel). This board is light in weight and can be suspended (with care) on its wiring for the duration of this operation.
8. Remove the two 4B. A. nuts and screws that secure the Paxolin panel on which is mounted the current transformer T2 (coloured red). This component also can be suspended on its wiring for a short time, but do not move it more than is necessary.
9. It is now possible to remove the two 2B. A. screws that secure the lower indicator tube mounting bracket. Pull the bracket gently towards the rear of the instrument until it is possible to grasp the tube that is to be changed.
10. Withdraw the tube and transfer the moulded hood to the replacement tube.
11. Replace and secure all brackets and panels in the reverse order from that by which they were removed.

REPLACEMENT OF RANGE INDICATOR LAMPS

59 1. Remove the eight 6B. A. screws that secure the Amplifier P-C board (left-hand panel viewed from the rear) and lower the board to the bench.

2. The row of seven lampholders can be seen beneath the G meter; the lampholders are held in place by means of spring clips. With the aid of a pair of long-nosed pliers, the appropriate lampholder can be withdrawn by pulling the spring-clip towards the rear of the instrument.

LIST OF COMPONENTS

When ordering spare parts, please quote the Instrument Type and Serial Numbers, and the circuit reference and value of the required component.

Resistors, Fixed

Cct. Ref	Value	Tol. %	Rating	Manufacturer or I. S. Style
R1	7.5k	0.05	1/4W	Welwyn Vishay 4804
R2	15k	0.05	1/4W	Welwyn Vishay 4804
R3	470Ω	10	1/4W	RC7-K
R4	2.7k	10	1/4W	RC7-K
R5	3.3k	10	1/4W	RC7-K
R6	330Ω	10	1/4W	RC7-K
R7	470Ω	10	1/4W	RC7-K
R8	4.7k	10	1/4W	RC7-K
R9	180Ω	10	1/4W	STC 502K/181/RY/1
R10	4.7Ω	10	1/4W	RC7-K
R11	470Ω	10	1/4W	RC7-K
R12	180Ω	10	1/4W	RC7-K
R13	2.7k	10	1/4W	RC7-K
R14	100k	10	1/4W	RC7-K
R15	3.9k	10	1/4W	RC7-K
R16	12k	10	1/4W	RC7-K
R17	12k	10	1/4W	RC7-K
R18	2.2k	10	1/4W	RC7-K
R19	39Ω	10	1/4W	RC7-K
R20	1.2k	10	1/4W	RC7-K
R21	240Ω	5	1/4W	Radiospares Metal Oxide
R22	15k	10	1/4W	RC7-K
R23	270	10	1/4W	RC7-K
R24	68	10	1/4W	RC7-K
R25	1.2k	10	1/4W	RC7-K
R26	1.5k	10	1/4W	RC7-K
R27	3.9k	10	1/4W	RC7-K
R28	3.3k	10	1/4W	RC7-K
R29	56k	10	1/4W	RC7-K
R30	1.5k	10	1/4W	RC7-K
R31	6.8k	10	1/4W	RC7-K
R32	1k	10	1/4W	RC7-K
R33	3.9k	10	1/4W	RC7-K
R34	560Ω	10	1/4W	RC7-K
R35	820Ω	10	1/4W	RC7-K
R36	180	10	1/4W	RC7-K
R37	33k	10	1/4W	RC7-K
R38	22k	10	1/4W	RC7-K
R39	27k	10	1/4W	RC7-K
R40	33k	10	1/4W	RC7-K

Cct. Ref	Value	Tol. %	Rating	Manufacturer or I. S. Style
R41	2.2k	2	1/4W	RC2-E
R42	2.2k	2	1/4W	RC2-E
R43	4.7k	10	1/4W	RC7-K
R44	4.7k	10	1/4W	RC7-K
R45	100 to 47Ω AIC §	5	1/10W	Radio Resistor Type LX
R46	10to 4.7Ω AIC §	5	1/10W	Radio Resistor Type LX
R47	220Ω to 22Ω AIC §	5	1/10W	Radio Resistor Type LX
R48	10k	10	1/4W	RC7-K
R49	8.2k	10	1/4W	RC7-K
R50	1.2k	10	1/4W	RC7-K
R51	6.8k	10	1/4W	RC7-K
R52	8.2k	10	1/4W	RC7-K
R53	2.2k	10	1/4W	RC7-K
R54	1k	10	1/4W	RC7-K
R55	2.2k	2	1/4W	RC2-E
R56	2.2k	2	1/4W	RC2-E
R57	4.7k	10	1/4W	RC7-K
R58	4.7k	10	1/4W	RC7-K
R59	1MΩ	+0 -0.1%	1W	Alma MF MA/1
R60	39k	10	1/4W	RC7-K
R61	39k	10	1/4W	RC7-K
R62	39k	10	1/4W	RC7-K
R63	39k	10	1/4W	RC7-K
R64	39k	10	1/4W	RC7-K
R65	180Ω	10	1/4W	RC7-K
R66	39k	10	1/4W	RC7-K
R67	1k	0.1	1/4W	Alma MF MA/1/4
R68	1k	0.1	1/4W	Alma MF MA/1/4
R69	100k	1	1/4W	RC2-E
R70	18k	10	1/4W	RC7-K
R71	18k	10	1/4W	RC7-K
R72	1.8k	10	1/4W	RC7-K
R73	56k	10	1/4W	RC7-K
R74	33k	10	1/4W	RC7-K
R75	33k	10	1/4W	RC7-K
R76	56k	10	1/4W	RC7-K
R77	1.8k	10	1/4W	RC7-K
R78	18k	10	1/4W	RC7-K
R79	18k	10	1/4W	RC7-K
R80	560Ω	10	1/4W	RC7-K
R81	560Ω	10	1/4W	RC7-K
R82	2.2k	2	1/4W	RC2-E

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§ See footnote below C20.

Cct. Ref	Value	Tol. %	Rating	Manufacturer or I. S. Style
R83	100k	1	1/4W	RC2-E
R84	100k	1	1/4W	RC2-E
R85	15k	10	1/4W	RC7-K
R86	15k	10	1/4W	RC7-K
R87	100Ω	10	1/4W	RC7-K
R88	100k	1	1/4W	RC2-E
R89	100k	1	1/4W	RC2-E
R90	470Ω	10	1/4W	RC7-K
R91	1.2k	10	1/4W	RC7-K
R92	18k	10	1/4W	RC7-K
R93	1.2k	10	1/4W	RC7-K
R94	2.2k	10	1/4W	RC7-K
R95	39k	10	1/4W	RC7-K
R96	22k	10	1/4W	RC7-K
R97	56Ω	10	1/4W	RC7-K
R98	470Ω	10	1/4W	RC7-K
R99	2.7k	10	1/4W	RC7-K
R100	10Ω	10	1/2W	RC7-H
R101	180k	10	1/4W	RC7-K
R102	180k	10	1/4W	RC7-K
R103	10Ω	10	1/4W	RC7-K
R104	33k	10	2W	Radio Resistor Type 0
R105	51k	10	1W	RC7-H
R106	1.2k	10	1/4W	RC7-K
R107	240Ω	5	1/4W	Radio Spares Metal Oxide
R108	1k	10	1/4W	RC7-K
R109	Not Used			
R110	10k	10	1/4W	RC7-K
R111	330k	10	1/4W	RC7-K
R112	9970Ω	0.1		Alma MF MA/1/4
R113	99800Ω	0.1		Alma MF MA/1/4
R114	6.8k	10	1/4W	RC7-K
R115	3.3k	10	1/4W	RC7-K
R116	27k	10	1/4W	RC7-K
R117	68Ω	10	1/4W	RC7-K
R118	100k	1		Welwyn C21
R119	100k	1		Welwyn C21
R120	1M	5	1W	Electrosil CJ32
Resistors, Variable				
RV1	Not Used			
RV2	10k	20	1W	Plessey E-CP 161003 Linear
RV3	1k	3	1/2W	Gen. Controls PMM 155/1K/10
RV4	1k	3	1/2W	Gen. Controls PMM 155/1K/10
RV5	10k	20	1W	Plessey E-CP161003 Linear

Cct. Ref	Value	Tol. %	Rating	Manufacturer or I. S. Style
RV6	10k	20	1W	Plessey E-CP 161003 Linear
RV7	1k	5	1/2W	Reliance WL35/PC Linear
RV8	1k	5	1/2W	Reliance WL35/PC Linear
RV9	20k	20	1/4W	Morganite Type U (3/4" spindle length)
RV10	1k	5	1/4W	Reliance WL35/PC Linear
RV11	1k	5	1/4W	Reliance WL35/PC Linear
RV12	20k	20	1/4W	Morganite Type U (3/4" spindle length)
RV13 to RV17	Not Used			
RV18	4.7k	20	1/4W	Plessey MP Dealer
RV19	500Ω	5		Reliance WL35/PC
RV20	500Ω	5	1/4W	Reliance WL35/PC
Capacitors				Manufacturer & Type
C1	13250p * 21000p ‡	1	200V	Johnson Matthey C33W
C2	6600p * 10660p ‡	0.5	200V	Johnson Matthey C33W
C3	700p	10	125V	GEC Polystyrene PF
C4	400μ	+50 -20	15V	Waycom Printilyte
C5	50μ	+50 -10	6V	Mullard C426 AR/C50
C6	400μ	+50 -20	15V	Waycom Printilyte
C7	400μ	+50 -20	15V	Waycom Printilyte
C8	2000p	10	150V	G. E. C. PFT (Polyester)
C9	2.75-15p	variable		Erie 3116C
C10	4-13.5p	variable		Stratton 580
C11	30p 70p §	2	125V	G. E. C. PF (Polyester)
C12	9900p	0.5		J & M. Silverstar (Silver Mica)
C13	2.75-15p	variable		Erie 3116C
C14	990p	0.5		J & M. Silverstar (Silver Mica)
C15	92p	±2pF	125V	G. E. C. PF(Polyester)
C16	2.75-15p	variable		Erie 3116C
C17	0.047μ	20	250V	Wima Elec. MKT
C18	400μ	+50 -10	10V	Mullard Elec. C426 AR/D400
C19	0.1μ	1	125V	G. E. C. PF(Polyester)
C20	200μ	+50 -10	10V	Mullard Elec. C426 AR/D200

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* This value fitted for operating frequency of 1592Hz

‡ " " " " " " " 1000Hz

§ Value selected during manufacture. If replacement necessary fit component of similar value to original. In some models these components may not be fitted.

Cct. Ref	Value	Tol. %	Rating	Manufacturer & Type
C21	200µ	+50 -10	10V	Mullard Elec. C426 AR/D200
C22	64µ	+50 -10	10V	Mullard Elec. C426 AR/D64
C23	5000p	1	125V	G. E. C. PF(Polyester)
C24	16µ	+50 -10	10V	Mullard C426 AR/D16
C25	400µ	+50 -10	15V	Wima Elec. Printilyte
C26	0.1µ	10	125V	Wima Elec. T. F. M.
C27	200µ	+50 -10	10V	Mullard Elec. C426 AR/D200
C28	300p	2	125V	G. E. C. PF(Polyester)
C29	200p	2	125V	G. E. C. PF(Polyester)
C30	400µ	+50 -10	15V	Wima Elec. Printilyte
C31	0.01µ	2	125V	G. E. C. PF(Polyester)
C32	0.01µ	2	125V	G. E. C. PF(Polyester)
C33	200µ	+50 -10	10V	Mullard Elec. C426 AR/D200
C34	200µ	+50 -10	10V	Mullard Elec. C426 AR/D200
C35	64µ	+50 -10	10V	Mullard Elec. C426 AR/D64
C36	200µ	+50 -10	10V	Mullard Elec. C426 AR/D200
C37	0.33µ	10	125V	Wima Elec. T. F. M.
C38	1µ	+100 -20	60V(d. c.)	Wima Elec. MKS
C39	10µ	+50 -20	6V	Waycom Printilyte
C40	0.33µ	10	125V	Wima Elec. T. F. M.
C41	1µ		6V	Plessey Elec. CE23006/12
C42	6.4µ	+50 -10	25V	Mullard Elec. C426 AR/F6.4
C43	6.4µ	+50/-10	25V	Mullard Elec. C426 AR/F6.4
C44	400µ	+50/-10	15V	Wima Elec. Printilyte
C45	Not Used			
C46	2000p	5	125V	G. E. C. Elec. PF(Polyester)
C47	2000p	5	125V	G. E. C. Elec. PF(Polyester)
C48	Not Used			
C49	Not Used			
C50	80µ	+50 -10	25V	Mullard Elec. C426 AR/F80
C51	80µ	+50 -10	25V	Mullard Elec. C426 AR/F80
C52	80µ	+50 -10	25V	Mullard Elec. C426 AR/F80

Cct. Ref	Value	Tol. %	Rating	Manufacturer & Type
C53	64µ	+50 -10	64V	Mullard Elec. C437 AR/H64
C54	16µ	+50 -20	350V	Hunts Elec. JF. 413T
C55	16µ	+50 -20	350V	Hunts Elec. JF. 413T
C56	80µ	+50 -20	16V	Mullard Elec. C426 CB/E80
C57	80µ	+50 -20	16V	Mullard Elec. C426 CB/E80
C58	10µ	+50 -20	6V	Waycom Printilyte
C59	0.01	10	150V	G. E. C. PFT(Polyester)
C60	2500µ	+100 -20	12V	T. C. C. CE1 99B
C61	§			
C62	Not Used			
C63				
C64				
C65				
C66	50p	2	350V	G. E. C. (Polystyrene)
C67	2.75-15p variable			Erie 3116C
C68	0.33µ	10	125V	Wima Elec. T. F. M.
C69	0.33µ	10	125V	Wima Elec. T. F. M.
C70	10µ		15V	T. C. C. CE4H
C71	10µ		15V	T. C. C. CE4H
C72	2000p	10	150V	G. E. C. PFT(Polyester)
C73-C80	Not Used			
C81	4.7nF * 10nF ‡	5	160V	Waycom 'Tropyfol' F
C82	47nF *	5	160V	Waycom 'Tropyfol' F
C83	33nF ‡	5	160V	Waycom 'Tropyfol' F
C84	30p	20	125V	Salford Polystyrene PF

Transistors

Cct. Ref	Type	Manufacturer
VT1	40232	RCA
VT2	40232	RCA
VT3	40232	RCA
VT4	40232	RCA
VT5	2G309	Texas
VT6	2G374	Texas
VT7	2N1304	Texas
VT8	2G374	Texas
VT9	2G374	Texas
VT10	2N1304	Texas

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* and ‡ see notes below C20

Cct. Ref	Type	Manufacturer
VT11	2G374	Texas
VT12	2G374	Texas
VT13	2G374	Texas
VT14	2G374	Texas
VT15	2G374	Texas
VT16	2G374	Texas
VT17	2G374	Texas
VT18	2G374	Texas
VT19	Not Used	
VT20	OC205	Mullard
VT21	2G374	Texas
VT22	2G374	Texas
VT23	OC201	Mullard
VT24	Not Used	
VT25	Not Used	
VT26	40232	RCA
Diodes		
MR1	OA200	Mullard
MR2	OA200	Mullard
MR3	OA91	Mullard
MR4	OA200	Mullard
MR5	OA200	Mullard
MR6	OA200	Mullard
MR7	OA200	Mullard
MR8	OA202	Mullard
MR9	OA10	Mullard
MR10	OAZ201	Mullard
MR11	IS131	Texas
MR12	IS131	Texas
MR13	IS131	Texas
MR14	IS131	Texas
MR15	BYX10	Mullard
MR16	IS131	Texas
MR17	IS131	Texas
MR18	IS131	Texas
MR19	IS131	Texas
MR20	OA202	Mullard
MR21	OA10	Mullard
MR22	OA202	Mullard
MR23	OAZ213	Mullard
Miscellaneous		
V1, V2, V3, V4, V5, V6	GN4	STC
V7, V8	SL166(Amber)	Arcolectric

Misc cont.

ILP1 to ILP7	Indicator Lamp 6.5V, 0.1A LES
T1	Voltage Transformer WK Dwg. D12341
T2	Current Transformer WK Dwg. D12342
TH1	Thermistor STC Type R14
L2	Detector Coil Assy. WK Dwg. D12370/1 (1592Hz)
T5	Power Transformer WK Dwg. D12418
F1	Power Fuse 0.5A Bewick TDC134 (Slow Blow)
M1	G-Meter } Sangamo Weston S157
M2	C-Meter

Range switch	WK Dwg. D12334
S/D Switch	WK Dwg. D12389
Function Switch	WK Dwg. D12340
Polarity Switches (PMC, PMG)	WK Dwg. D12327

<u>Components List for Early Oscillator</u> (see Appendix 1)

Cct. Ref	Value	Tol. %	Rating	Manufacturer or I. S. Style
R1	6.8k	10	1/4W	RC7-K
R2	470Ω	10	1/4W	RC7-K
R3	10k	10	1/4W	RC7-K
R4	180Ω	10	1/4W	RC7-K
R5	1.8k	10	1/4W	RC7-K
R6	Not part of oscillator			
R7	2.2k	10	1/4W	RC7-K
R8	Not part of oscillator			
R9	1.8k	10	1/4W	RC7-K
R10	4.7Ω	10	1/4W	RC7-K
R11	4.7Ω	10	1/4W	RC7-K
R12	180Ω	10	1/4W	RC7-K
R65	180Ω	10	1/4W	RC7-K
RV1	1k	5	1/2W	Reliance WL35/PC
C1	2500µ	+100 -20	12V	TCC CE199B
C2	6.4µ	+50 -10	25V	Mullard C426 AR/F6.4
C3	0.1µ	1	125V	G. E. C. PF(Polyester)
C4	64µ	+50 -10	10V	Mullard C426 AR/D64
C5	200µ	+50 -10	10V	Mullard C426 AR/D200

VT1	2G309	Texas	MR9	OA10	Mullard
VT2	2G309	Texas	MR21	OA10	Mullard
VT3	2G385	Texas			
VT4	2G385	Texas			

TH1	STC Type R24
TH2	STC Type K22
L1	Coil Sub-assembly. WK Dwg. D12396A

APPENDIX 1 - EARLY OSCILLATOR

1 Early models of the B641 were fitted with a thermistor bridge type of oscillator, which does not have quite the same purity of waveform as the later Wien Bridge Oscillator.

2 The circuit diagram of the oscillator is given in fig. A1-1. The oscillator comprises a tuned high gain amplifier which is made to oscillate by the application of positive feedback via R12/R65. Negative feedback is also applied to the amplifier to control the level of oscillation. The negative feedback path incorporates a thermistor, TH1, so that the oscillator output is unaffected by variations of load or supply voltage. However, TH1 is unable to differentiate between an incipient change in output level and a change in ambient temperature; this is overcome by means of a second thermistor, TH2, in the positive feedback path.

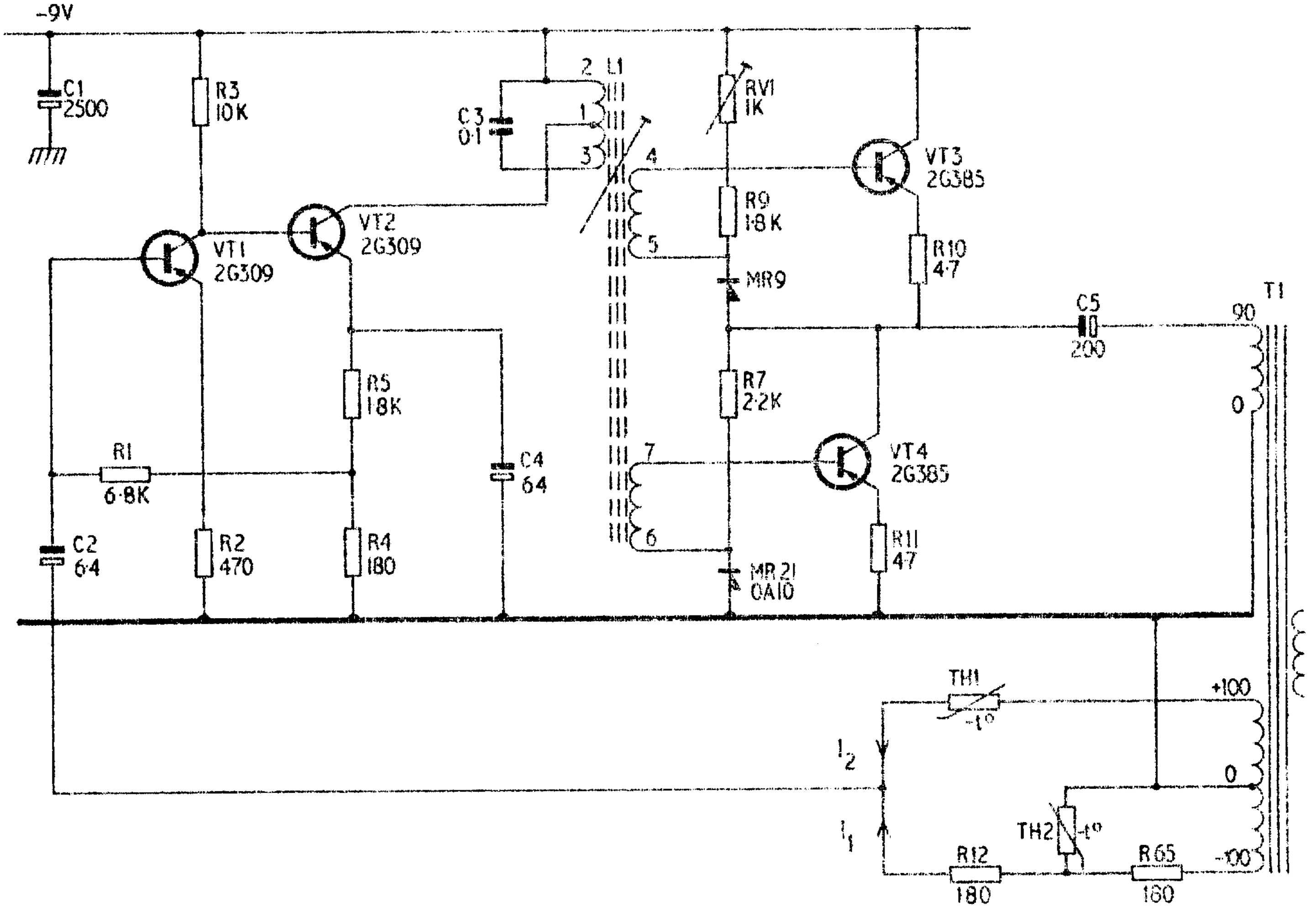


Fig. A1-1. Early B641 Oscillator Circuit.

3 The transformer windings are so arranged that the current I_1 through R12/R65 reinforces the input to the amplifier, thereby causing oscillation at a frequency determined by a tuned circuit in the forward path of the amplifier. At low signal levels, the resistance of TH1 is high and therefore the current I_2 is low. As the signal level increases, the resistance of TH1 falls and I_2 increases. The loop gain of the system is made sufficiently high, and the thermistor bridge winding symmetrical, so that the system stabilizes at a level at which I_1 and I_2 are very nearly equal. At this point, the resistance of TH1 is approximately equal to that of the network comprising R12, R65 and thermistor TH2.

4 The tuned amplifier comprises the transistors VT1 to VT4 inclusive. VT1 and VT2, which form the high gain amplifier, are connected as a d. c. feedback pair to give improved stability over the operating temperature range.

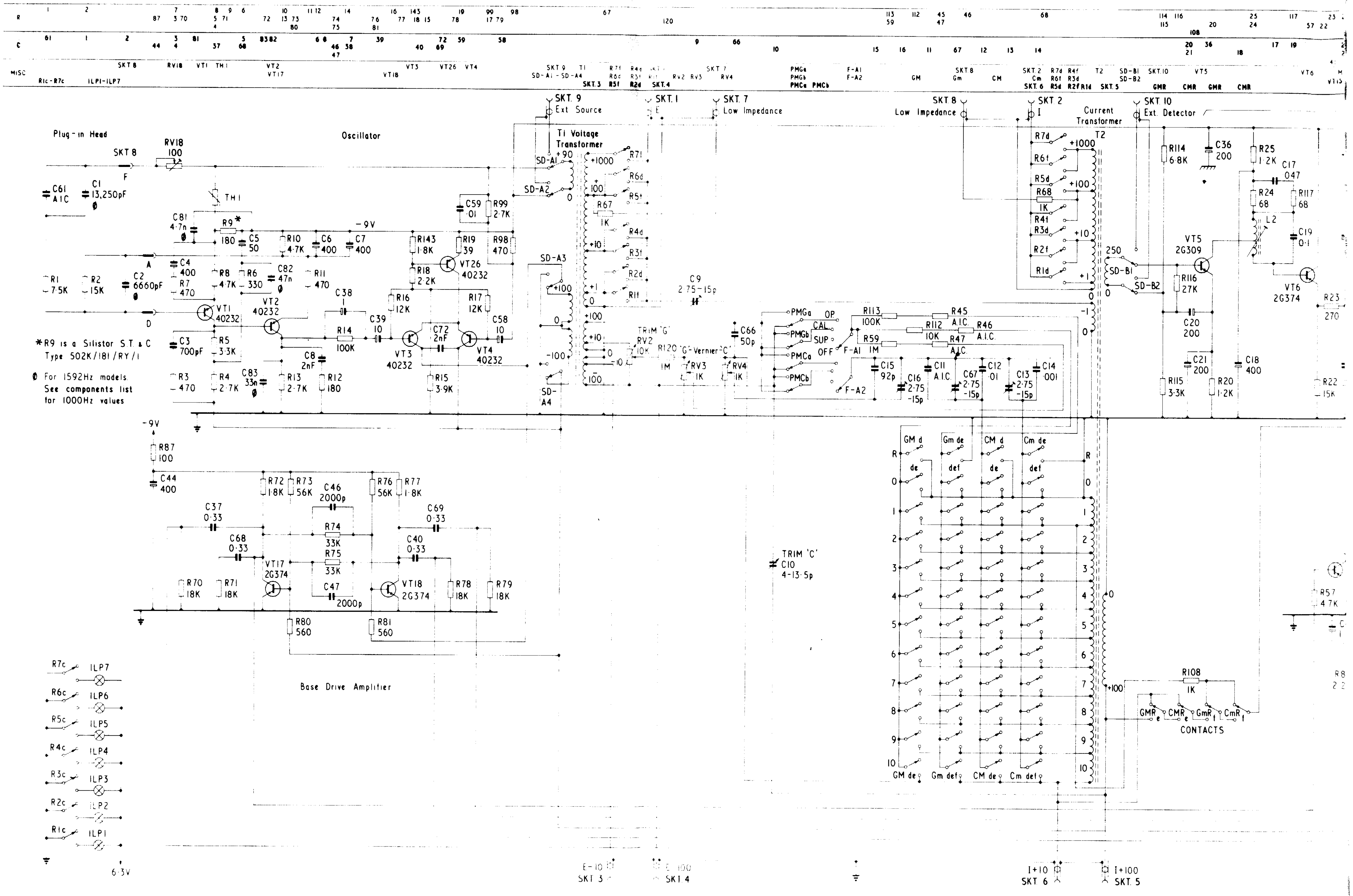
5 Initially, the collector of VT1 and the base of VT2 are at the supply potential and so VT2 conducts. The potential at the emitter of VT2 approaches that of the supply and is divided by the potential divider R4/R5. The potential at the junction of R4/R5 is fed back via R1 to the base of VT1, so causing VT1 to conduct. VT2 base, and hence emitter potential is reduced and this, in turn, reduces the potential at VT2 base.

6 The system is stabilized at a level determined by the feedback tapping point on VT2 emitter. The emitter circuit of VT1 is left unbypassed and the resulting current feedback helps to stabilize the operating conditions. The d. c. feedback to VT1 base greatly reduces the tendency of the base/emitter potential to drift with temperature variation; this ensures that the operating point for VT2 collector is reasonably constant. The emitter of VT2 is decoupled by C4 to prevent feedback at the operating frequency. The collector load for VT2 is the tuned circuit comprising C3 and the primary of L1. This circuit is tuned to 1592Hz and determines the operating frequency of the oscillator.

7 The two secondaries of L1 give a push-pull input to VT3 and VT4, which operate as a Class B pair. Diodes MR9 and MR21 provide a small forward bias for VT3 and VT4 to reduce the cross-over

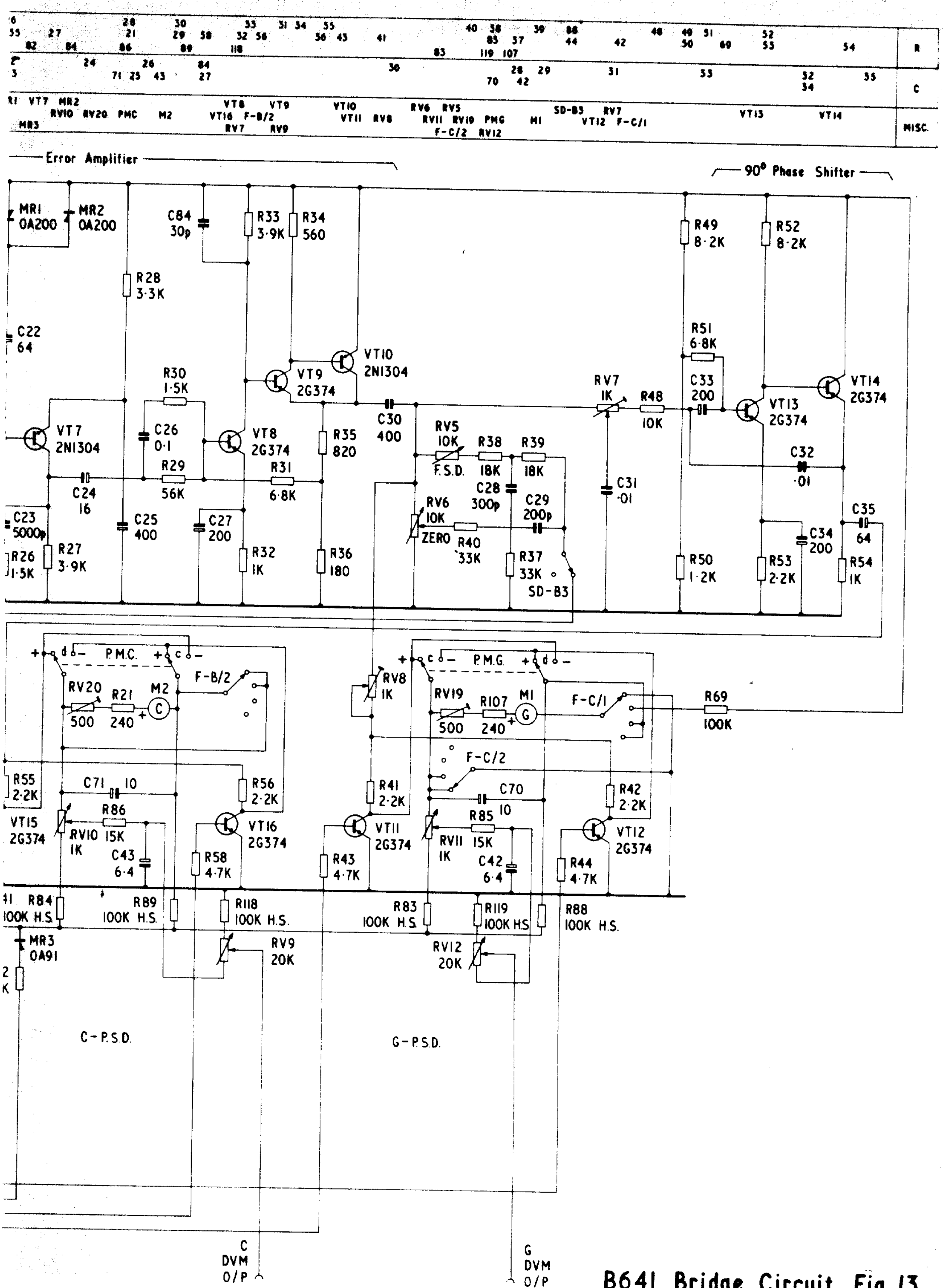
distortion; the use of diodes instead of resistors stabilizes this bias against changes in supply voltage. Potentiometer RV1 is adjusted to equalize the direct current flowing in each half of the output stage, thus reducing second harmonic distortion to a minimum. Resistors R10 and R11 prevent excessive direct currents in the output stage should the voltage transformer T1 be accidentally short circuited.

8 If this oscillator is fitted, substitute L1 for C60 in paragraph 41 (Oscillator Frequency) of the main text.

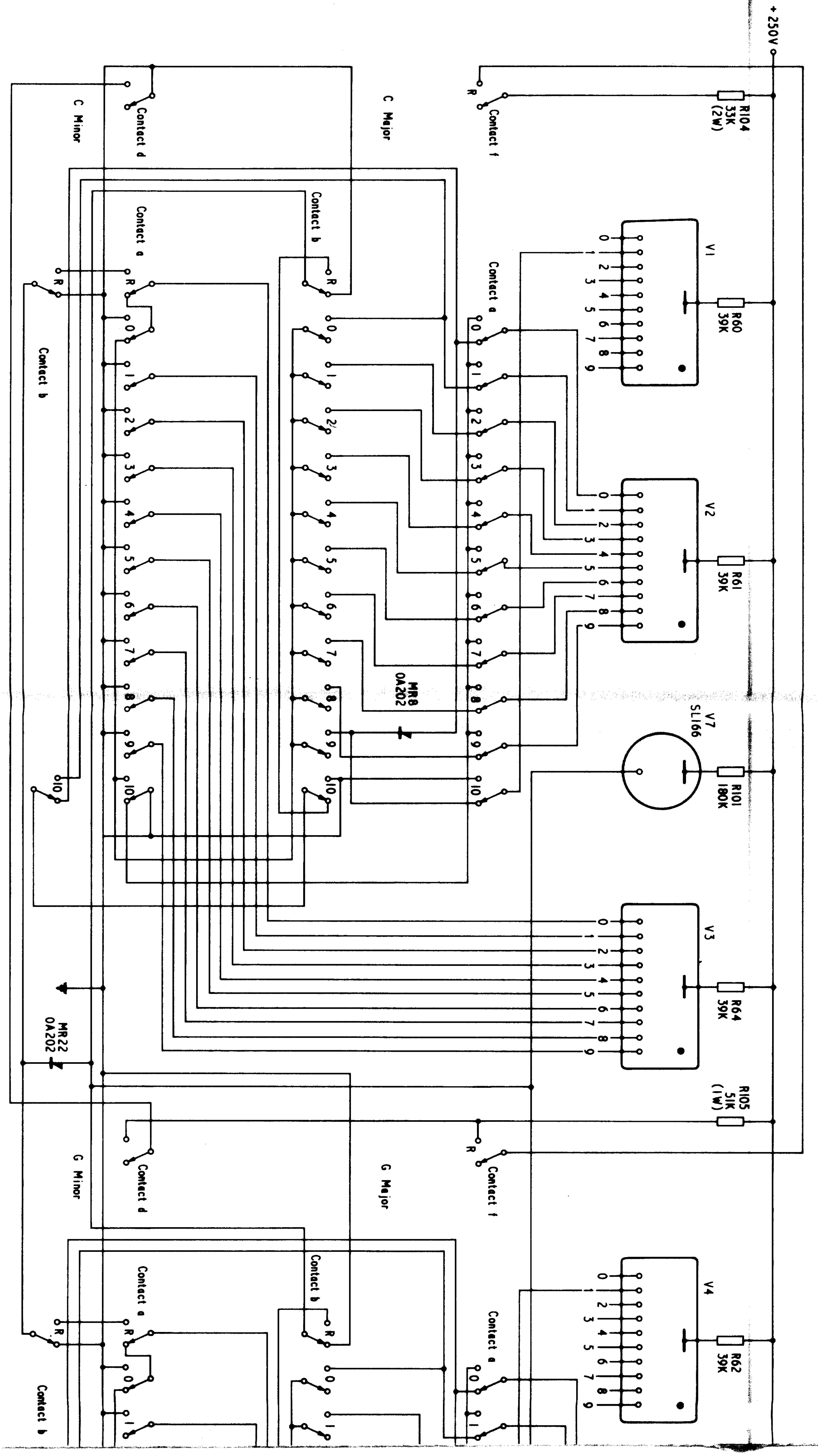


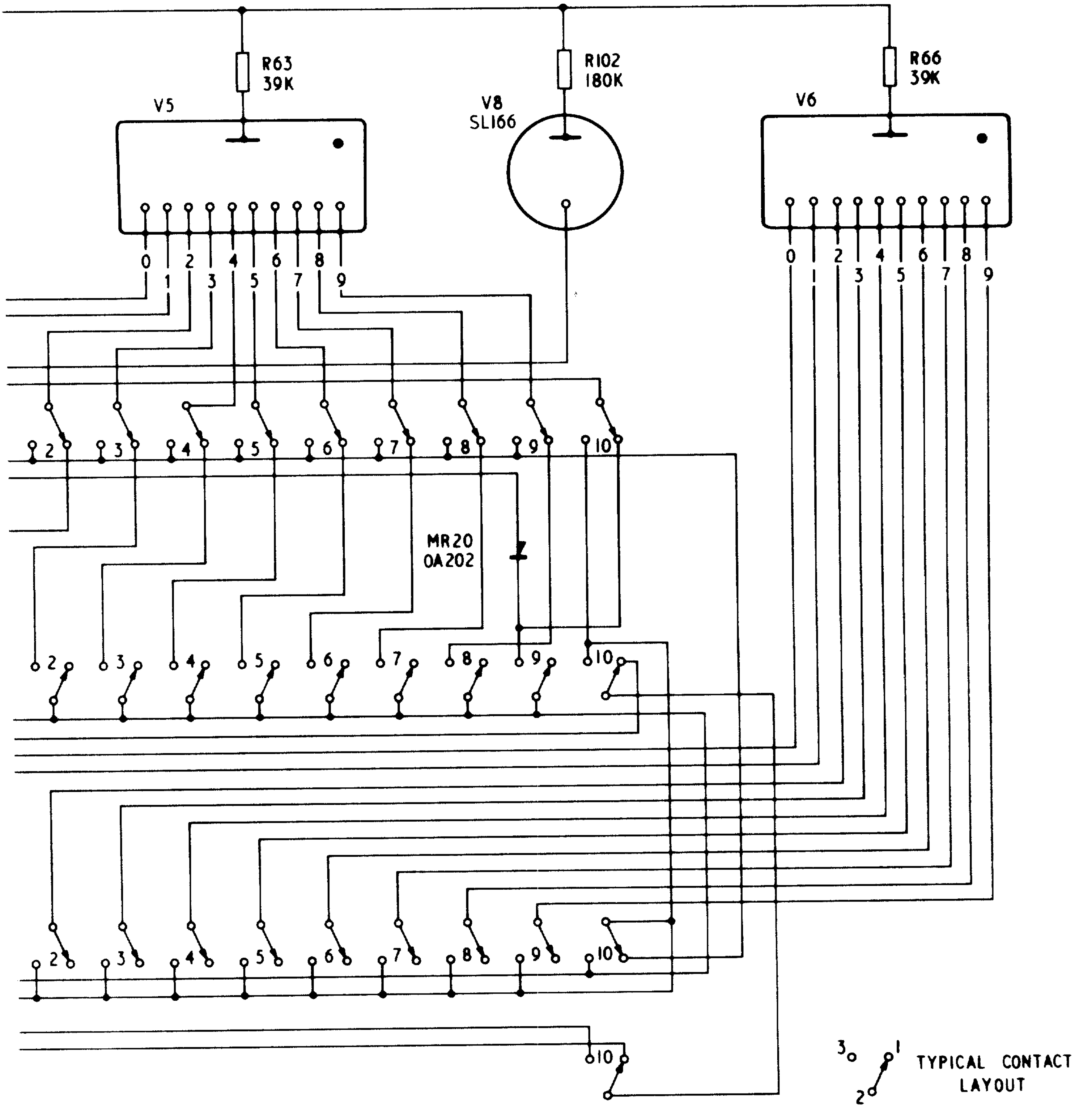
*R9 is a Silistor S.T. & C Type 502K/181/RY/1

0 For 1592Hz models See components list for 1000Hz values

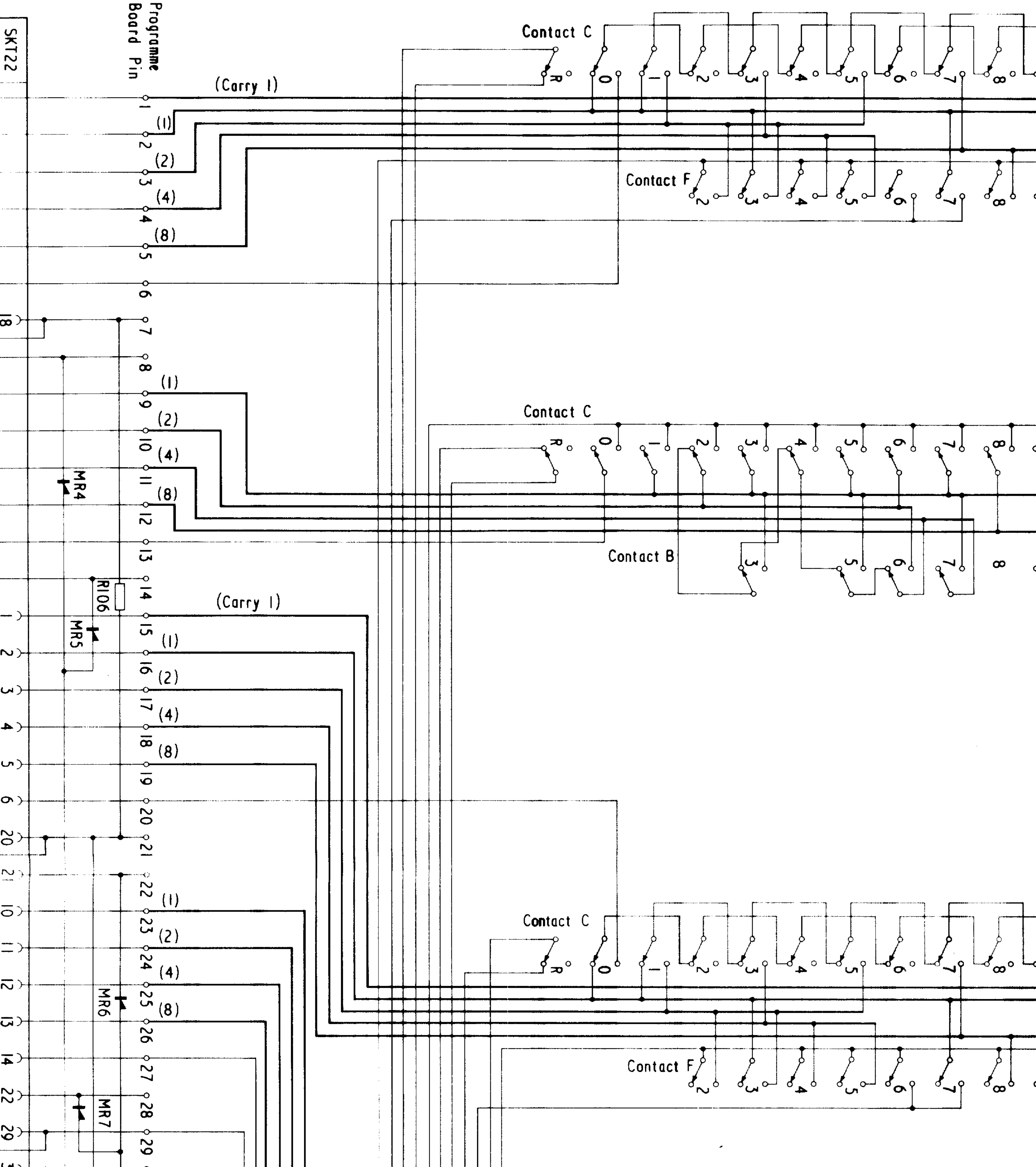


B641 Bridge Circuit. Fig. 13


+250V
R104
33K
(2W)
Contact f
R
C Major
C Minor
Contact d
Contact b
Contact a
V1
R60
39K
V2
R61
39K
V7
SL166
R101
180K
MR8
OA202
V3
R64
39K
R105
51K
(1W)
MR22
OA202
G Major
G Minor
Contact f
Contact d
Contact b
Contact a
V4
R62
39K
0
1
2
3
4
5
6
7
8
9
10



Digital Indicator Switching Circuit Fig. 14


SKT22
Programme Board Pin
Contact C
Contact F
Contact B
(Carry 1)
(1)
(2)
(4)
(8)
MR4
MR5
MR6
MR7
R106
R
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
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19
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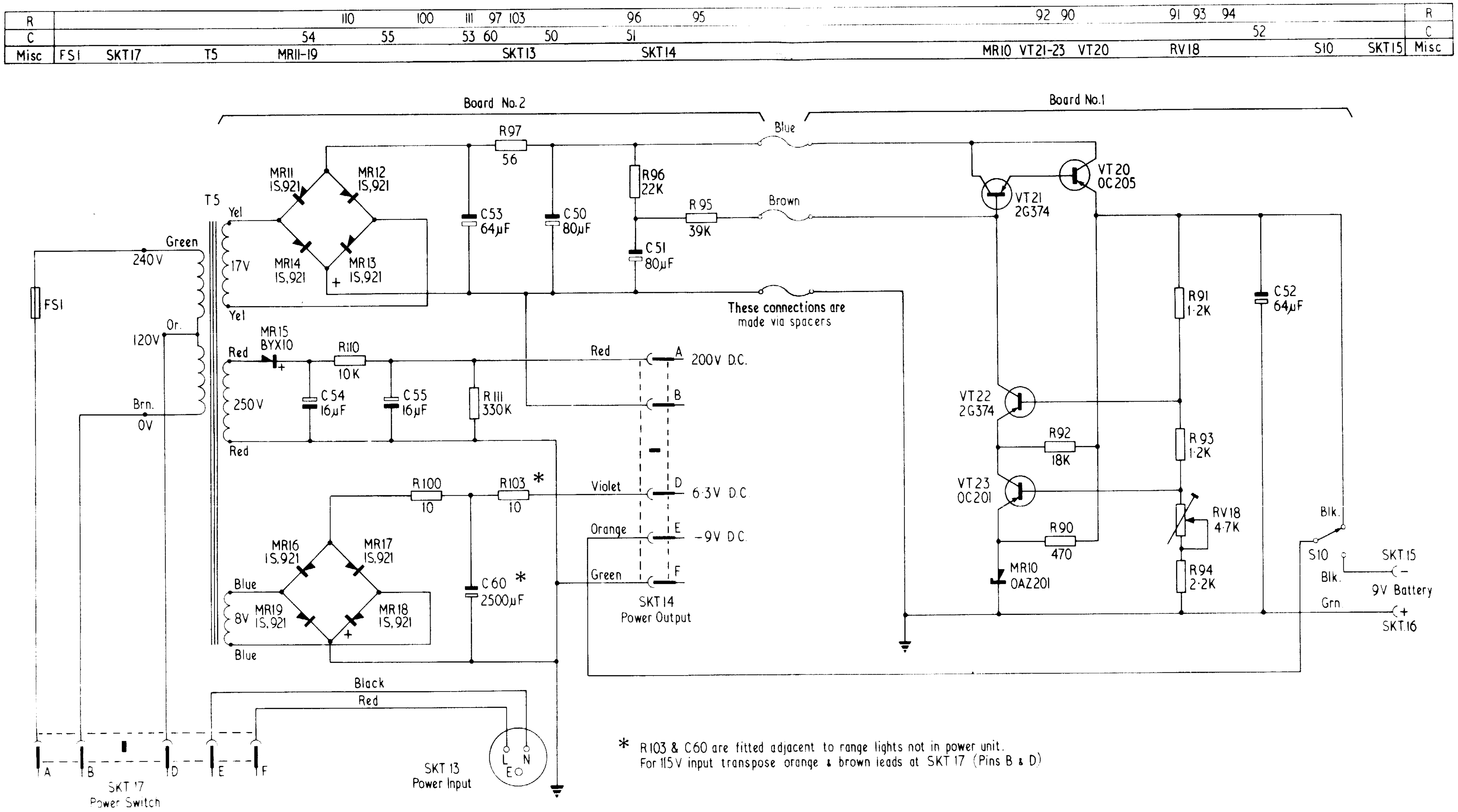

* R103 & C60 are fitted adjacent to range lights not in power unit.
For 115V input transpose orange & brown leads at SKT 17 (Pins B & D)

B641: Power Supply Unit. Fig.16