

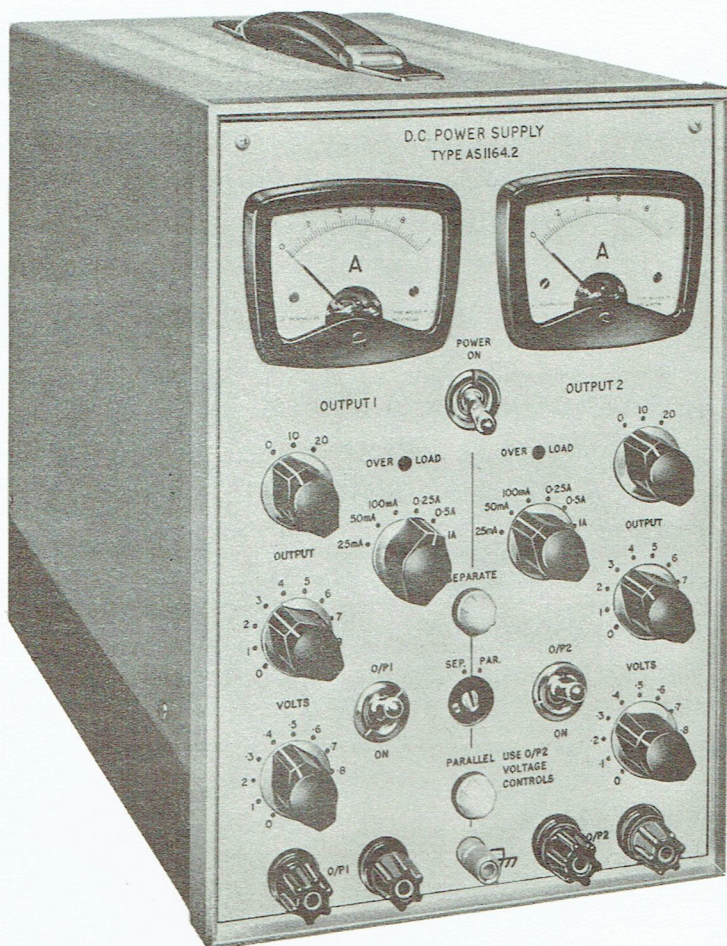
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**TWIN TRANSISTOR
POWER SUPPLY
AS 1164 . 2**

SOLARTRON

TECHNICAL MANUAL

TWIN TRANSISTOR POWER SUPPLY AS 1164.2



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SECTION 1.

SPECIFICATION.

GENERAL.

The twin transistor power supply consists of two separate supplies, each with individual controls, mounted in the same case. By means of a guarded switch, the two channels may be used in parallel, with voltage control automatically transferred to the right hand channel. An external link may be used so that the two supplies can be operated in series. A fully electronic proportional control system of overload protection is provided which is self resetting except when the supply is operated in the series condition when the self resetting facility does not operate for load currents in excess of 40% of the limiter setting.

OUTPUT VOLTAGE.

Two outputs, each variable from 0 - 30 V by decade switches providing steps of 10, 1, and 0.1 V. The accuracy of voltage setting at room temperature-off load is $\pm 2\%$, + 2 mV.

OUTPUT CURRENT.

Up to 1 Amp may be drawn from each of the outputs. Output current meters of grade 1 accuracy are provided in each channel, linked terminals are available into which an external meter may be connected.

REGULATION.

The variation in output voltage, for a change in output current from 0 - full load at the maximum voltage setting of 30 V, is less than 30 mV, i. e. 0.1%.

STABILITY.

The change in output voltage caused by a change in supply of $\pm 7\%$ is typically 2 mV and always less than 5 mV. (Stability factor greater than 1000 : 1).

RIPPLE AND NOISE.

Typically 1 mV peak-to-peak. (less than 2 mV peak-to-peak).

AMBIENT TEMPERATURE RATING.

The power supply will work at ambient temperatures up to 35°C with no restriction on use. Provided overload conditions are not allowed to persist for longer than 5 minutes on any occasion, the unit may be worked in ambient temperatures up to 45°C.

OUTPUT IMPEDANCE.

Less than 0.35 ohms up to 100 kc/s.

CHASSIS ISOLATION.

The supplies may be operated with the output terminals at potentials up to ± 250 V with respect to chassis. A maximum potential of 500 V can exist between the two supplies.

OVERLOAD PROTECTION SYSTEM.

Self-resetting, proportional control - fully electronic. The maximum current output, i. e. the point at which the overload circuit becomes operative, may be set independently on each supply to any one of six spot values of nominally 1 Amp, 0.5 Amp, 250 m Amp, 100 m Amp, 50 m Amp, and 25 m Amp.

A.C. SUPPLY REQUIREMENTS.

100 - 125 V and 200 - 250 V a.c. 50 - 60 c/s.

DIMENSIONS.

14.5/8 ins. long x 7.5/16 ins. wide x 11.3/8 ins. high overall.
(36.5 cms. x 18.5 cms. x 28.8 cms.)

WEIGHT.

25 lbs. approximately.
(11.33 kg)

SECTION 2.

OPERATING INSTRUCTIONS.

FRONT PANEL CONTROLS.

The front panel controls are considered in three groups as follows :

- 1) Those controls relating to output 1.
- 2) Those controls relating to output 2.
- 3) Those controls relating to both supplies.

Viewing the front panel from the front, group 1 is on the left, group 2 on the right and group 3 in the centre. The controls in group 2 are a mirrored image of those in group 1 and will not be described.

DECADE VOLTS.

Three switches in a vertical line on the extreme left of the panel. These control the output voltage of output 1 in steps of 10, 1 and 0.1 volts.

N.B. During parallel operation, the voltage output of both supplies is controlled by the Decade Volts controls of output 2 (extreme right of panel). The output 1 controls do not operate.

OVERLOAD.

An indicator on the left centre of the front panel which is lit when the overload limiter is operating. This is associated with a switch which presets the load current at which the limiter comes into operation.

O/P1 - ON.

The output switch which isolates the positive output terminal from the power supply.

MAINS - ON.

The supply switch which controls the a. c. supply to the transformer primary.

SEPARATE.

An indicator lamp which is lit when the two supplies are set for independent operation.

SEP - PAR.

A two position switch to determine the operating mode of power supply viz. Separate or parallel.

PARALLEL.

An indicator lamp which is lit when the two supplies are set for parallel operation.

O/P1.

The terminals from which output 1 is taken (separate operation only). The red terminal is the positive pole of the supply.

O/P2.

The terminals from which output 2 is taken. The red terminal is the positive pole of the supply.

¹ | (TL5) A terminal which connects to chassis.
////

OPERATION.

When the instrument first arrives, check it for superficial damage. Set the mains voltage selector panel to the stated nominal local supply voltage. Check that the fuse rating is correct for the supply voltage in use viz :-

200 - 250 V - 2.5 A

100 - 125 V - 5 A

Connections to the power supply and adjustments of the controls will vary according to the mode of operation of the supply. The remainder of these instructions will therefore be written under three sections corresponding to separate, series, and parallel operation.

SEPARATE OPERATION.

This mode of operation is used when one or two loads have to be supplied at different potentials and different currents. The voltage across each load cannot exceed 30 volts and the current through each load must be less than 1 Amp. Set the SEP/PAR switch to SEP; connect the loads to the output terminals as required; set the decade voltage switches to the required output potential. Estimate the maximum current which can be drawn by the load without damage to it, and set the relevant overload selector switch to a suitable range.

Switch on the a. c. mains, observe that the 'separate' lamp is lit. Switch O/P1 and O/P2 as required, check that neither overload indicator is lit. Where a common line exists between the two loads, the relevant terminals of the supply may be commoned.

SERIES OPERATION.

Where a single load is to be supplied at a potential between 30 and 60 V, the two supplies may be connected in series by connecting the positive pole of output 2 to the negative pole of output 1. The load is then connected between the positive pole of output 1 and the negative of output 2.

Set the SEP/PAR switch to SEP and adjust the decade voltage selectors so that the sum of the six control settings is equal to the required voltage.

Set both overload selector switches to the maximum safe output current. Switch on the supply main and check that the SEP light is lit. Then switch on O/P1 and O/P2. Either of these switches will switch off the supply. Both meters should read the output load current. Check that neither overload indicator is lit.

PARALLEL OPERATION.

Where a single load is to be supplied at a potential between 0 - 30 V requiring currents between 1A and 2A the two supplies may be used in parallel. Connect the load between one pair of terminals. Control the output by the relevant output switch.

Set the SEP/PAR switch to PAR and adjust the decade voltage selector of output 2 to give the required output voltage. Set the two overload selectors such that the sum of the two settings is the required limiter setting.

Switch on the a. c. supply and check that the 'parallel' light is lit. Switch on the output. The load current is the sum of the readings on the two meters.

OPERATIONAL NOTES.

The output voltage may be changed when the power supply is in operation on load. The limiter current selector may be adjusted when the power supply is in operation on load. If the limiter comes into operation on either supply, the relevant overload lamp will light, and remain lit until the overload is removed or the limiter current selector adjusted. If the limiter fails to reset* when the overload is removed, switch off the power supply, or switch off the output switch, pause, then switch on again.

* series operation only.

SECTION 3.

CIRCUIT DESCRIPTION.

GENERAL.

The twin transistor power supply type AS 1164 consists of two similar supplies each capable of delivering 30 volts at 1 Amp stabilised. These supplies may be operated separately, in series, or in parallel. The output voltage of each supply is controlled by three switches, the first providing ten volt steps; the second, one volt steps; the third, 0.1 volt steps. A fourth switch associated with each supply presets the output load current at which the automatic limiter action comes into operation. Each output is independently switched. When the supplies are operated in parallel the controls of Output 2 override those of Output 1 and take over control of both supplies. The positive or negative poles of either supply may be earth referred to TL5.

TRANSFORMER.

The input from the a. c. supply main, passes through a supply switch and fuse into a mains voltage selector panel and on to the primary of the transformer. The primary is wound in two equal tapped halves for operation from 110 volt or 220 volt a. c. supplies. The tappings are arranged to accept any voltage from 100 to 125 volts in 5 volt steps, or from 200 to 250 volts in 10 volt steps.

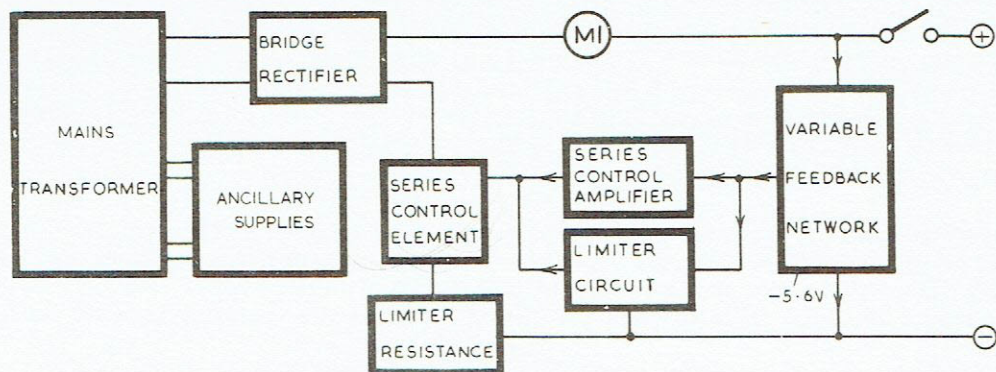


Figure 1. Block Diagram AS1164.2

The transformer has six secondary windings, three relating to output two, and three relating to output one. The first secondary provides the main power for output two, it is tapped and the taps are selected by wafers of the output voltage switches. S2A selects one of three taps according to the setting of the 10 V output voltage switch. S3A selects one of two taps according to the setting of the units volts switch. The second and third windings provide ancillary supplies required for the control amplifier of output two. The fourth, fifth and sixth secondaries are similar to the first, second and third secondaries, but relate to output one.

RECTIFIER.

The output from secondary one, is taken through the tap changing switches on to a bridge rectifier MR11-MR14. The rectified a.c. is then smoothed by the reservoir capacitor C2. The resistors R10 and R11 provide a discharge path across C2. The positive rectified voltage is then passed through a link across which an external meter can be connected if required, through the internal meter, and to the positive output terminal through the output switch S6.

LIMITER RESISTOR.

The load current returns to the supply through the negative terminal and passes immediately to the limiter resistor. This resistor, selected by S4, determines the current at which the limiter comes into operation. Preset currents of 25, 50, 100, 250 or 500 m A or of 1 Amp may be selected.

SERIES ELEMENT.

The series control element consists of three transistors VT4, VT5, and VT6, connected in parallel as a multiple emitter follower. They are driven on their bases by the emitter follower VT3.

THE FEEDBACK NETWORK.

The negative feedback network consists of R47-R67, R45, R46 and RV2. The resistors R47-R67 are connected in series from positive HT line to R45 and are shorted out by the switches S2/C, S3/C and S5 to vary the feedback ratio and therefore the output voltage. The lower end of the resistor chain is connected to a reference potential between -5.6 V and HT negative determined by the setting of RV2 and the resistors R45 and R46. C10 provides compensation for inductive pick-up in the delay network.

CONTROL AMPLIFIER.

The control amplifier consists of four transistors connected as two emitter coupled differential amplifiers in cascade. The first pair consists of VT9 and VT10, VT10 receives signal from the negative feedback chain on its base while VT9 is referred to a potential approximating to HT negative, and determined by the setting of RV1. R43 and C7 connected between the bases of VT9 and VT10 are incorporated to improve the transient response of the supply. They integrate any transient change in line voltage and slow down the rate of change of voltage at the base. The outputs from the collectors of VT9 and VT10 are directly coupled to the bases

of VT11 and VT12, two N.P.N. transistors. The collector of VT11 is connected directly to HT negative and the collector of VT12 connects through a load to +6.5 volts. The series-connected R-C network (C21 and R138) between the collector of VT12 and common rail provides loop stability by preventing undue variations in phase shift, thereby giving an improved output impedance characteristic. The output from the amplifier is taken from the collector of VT12 directly to the base of VT3.

OVERLOAD PROTECTION.

The power supply is protected from overload by a limiter stage with proportional control, this circuit is the subject of a patent application. The system of overload control is as follows:- When the emitter follower is connected with a fixed resistance in the emitter circuit and fixed-base potential, the current drawn through the transistor cannot exceed the value at which the IR drop in the emitter resistor exceeds the base potential.

A simple system of over current protection would therefore be to catch the base potential of the series element so that it could not fall below the level, which would give rise to an excess current into the output load. This method of protection however could lead to power over loading of the series element when the severity of the overload became great so that the whole of the reservoir capacitor potential appeared across the series element. To overcome this disadvantage the circuit which is used varies the voltage to which the base of the series element is clamped according to the severity of the overload. Thus in the presence of a short circuit across the output, the series elements are held back to a safe power dissipation.

A simplified circuit of the overload system is shown in Fig. 2. The base potential of the series element VT4, VT5, and VT6 in parallel, is normally controlled by the output voltage from the collector of VT12, through the emitter follower VT3, and will move more negatively as more power is demanded from the power supply. The emitter of VT7 is connected to the base of VT3. Under normal conditions this transistor is cut off. When the base of VT3 moves sufficiently negative that an overload current would flow, the emitter of VT7 moves more negative than its base. VT7 then conducts, clamping the base potential of VT3 to the base potential of VT7. The base potential of VT7 is set up by adjusting RV3 to make VT7 conduct at the required preset overload currents.

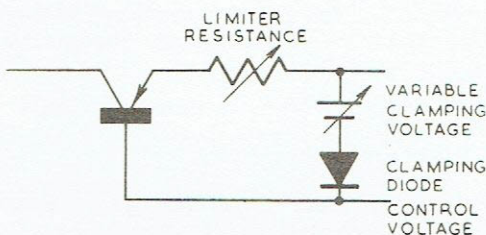


Figure 2. Simplified overload Control System.

R33 in the resistor chain containing RV3, is connected to the collector of VT8 which is connected on its base through R29 to the feedback resistors. In the presence of overload conditions on the supply, the voltage across the output terminal will tend to collapse making the base of VT10 and that of VT8 move negatively. This will cause the collector of VT8 to move more positive, reducing the negative voltage at the base of VT3 and thereby reducing the current through the series element. Thus the current output from the supply will be reduced as the severity of overload is increased. This enables the main series element to work at nearly constant power dissipation.

VT25 is the overload indicator switch, it consists of a transistor which is switched when the limiter transistor VT7 commences to conduct. VT25 then conducts, causing current to flow through the indicator lamp LP3.

ANCILLARY SUPPLIES.

The a.c. output from the second secondary of the transformer is rectified by MR1 and MR2 and smoothed by R1 into the reservoir capacitor C1. This supplies a negative unsmoothed voltage for the collector of VT3. The a.c. output from the third of the transformer secondary windings feeds two rectifier systems, one producing a positive output and the other a negative output. The positive output is smoothed by C5 and feeds the base of the series control element. The positive supply is then stabilised by the Zener diode MR9 fed through R6 to provide a positive 6.5 volt rail which supplies parts of the series control amplifier.

The output from the negative rectifier system is smoothed on the reservoir capacitor C4 and provides current to drive the overload indicator lamp LP3 and the transistor VT25. The remainder of the output from this supply is stabilised by the series control element VT1 controlled by the amplifier VT2. The stabilised

negative 10 volt output provides current for sections of the control amplifier and overload circuitry. It also feeds through R9 to the Zener diode MR10 which provides a -5.6 volts reference potential. Variations in the -10 volt line are fed to the base of VT2 through the resistor chain R7, R8. The emitter of VT2 is referred to HT negative through the Zener diode MR8. Control signals are taken from the collector of VT2 to the base of the series control element VT1.

The second power supply output 1 is similar in most respects to that which has just been described, except that the component reference numbers vary. The tap changing switches are duplicated, one set being connected to the output voltage controls of output 1, these are operational when two of the supplies are used independently. A second set of tap changing switches are ganged to the output controls of output two and come into operation when the two supplies work in parallel. Under these conditions the amplifier and overload circuits of output one are isolated by the separate/parallel switch S12.

SECTION 4.

SETTING UP AND TEST PROCEDURE.

GENERAL.

The information which follows is abstracted from the factory test procedure. The instrument leaves the factory fully set up and should not require further adjustment unless major repair work has been undertaken, or any of the preset controls has inadvertently been moved or replaced. The following test equipment is required to carry out the tests :-

TEST EQUIPMENT.

- Variable Voltage Transformer 0 - 250 volts, 50 c/s (Variac).
- A general Purpose Oscilloscope (Solartron CD 1183).
- Voltmeter Multi-range (Avometer Model 8).
- An Auxiliary Stabilised Power Supply (Solartron AS 757.4).
- A Load Resistor, 500 ohms Variable, 1 Amps rating.
- Voltmeter 0 - 30 volts d. c., 0.3% accurate (Electronic Instruments Ltd.)
- An Oscillator 25 c/s - 500 kc/s (Solartron CO 546).
- Paper Capacitor 16 Microfarads, 600 volts.
- Resistor High Stability, 1000 ohms, 1% (Erie Type 109).
- Insulation Tester, e.g. Megger 500 volts.
- Load resistor, 15 ohms variable, 5 Amps rating.
- Pulse Generator (Solartron GO 1101).
- Pulse Amplifier, Solartron TG48, (Refer Appendix I).

PRELIMINARY TESTS.

Insulation.

Before connecting the instrument to the a. c. supply, set all toggle switches to ON and set S12 to SEP. Use the Megger to check the insulation between chassis and OP1, chassis and OP2, OP1 and OP2. The insulation resistance must not be less than 10 megohms, check the insulation between the mains line terminal and chassis, between the mains line terminal and output 1, and between the mains line terminal and output 2. The insulation must not be less than 100 megohms.

MAINS VOLTAGE SELECTOR PANEL.

Set the mains voltage selector panel on the instrument to 250 volts, connect the mains lead from the instrument to the Variac and connect the Variac to the supply mains. Set the Variac to 250 volts and switch on the Variac and the instrument. Use the d. c. multi-range voltmeter to measure the d. c. voltage across C4, which should be approximately 23 volts. Select in turn all 10 positions of the mains voltage selector panel, in

each case adjusting the Variac to provide the required input voltage. Check that the voltmeter reading across C4 is the same ± 0.7 volts. Reset the mains selector and the Variac to 250 volts. Set all the decade voltage switches to zero and the current limiter selectors to 1 Amp. Turn RV3 and RV8 fully clockwise. Using the multi-range voltmeter connected across the terminals of output 1, and adjust RV6 for zero output, then connect the voltmeter across the terminals of output 2, and adjust RV1 for zero output. Use the 50 micro amp range for final adjustments of each supply. Connect the sub-standard voltmeter on the 20 volt range across the terminals of output 2. Set the decade voltage switches of output 2, to 10, 9, 1 and adjust RV2 to give 20 volts reading on the meter. Connect the meter to the terminals of output 1, set the decade voltage switches of output 1 to 10, 9, 1 and adjust RV7 to give a reading of 20 volts on the meter. Check the output voltage at all positions of each of the three decade switches on each of the two outputs. The voltage must be within $\pm 2\%$ of nominal. Monitor to -10 V line with the CRO and adjust RV4 and RV5 for minimum ripple.

LOAD SHARING.

Set the decade voltage selectors of both supplies to 10,9,1 and switch S12 to parallel. Set the mechanical zero's of the internal meters. Connect the 15 ohms load resistor across the terminals of output 2, and reduce the resistance until the load current is 2 Amps. The two internal meters must read within 50 mA of each other.

TRANSFORMER TAP SELECTION.

Remove all loads from the power supply. Connect the sub-standard voltmeter to measure the a. c. voltage applied to the bridge rectifier MR11-MR14 and then to the bridge rectifier MR26-MR29. Set S3 to 0 V and S2 to 0 V, note the voltage reading. Set S2 to 10 and 20, and then set S3 to 5; on each change of S2 or S3, note the new a. c. voltage. These should correspond to the voltages given in the following table. Turn S12 to SEP and repeat the measurements across MR26-MR29 adjusting S7 and S8.

TABLE 1.

Decade Switch Setting.	R. M. S. Voltage Across Rectifiers.
0 V	11.5 V
10 V	20.5 V
20 V	29.5 V
25 V	34 V

SETTING UP LIMITERS.

Set the decade switches to deliver an output voltage of 0.1 volts from each supply and place a short circuit across the terminals of output 1. Adjust RV8 so that the internal meter reads 0.6 Amps. Connect the sub-standard meter to the external meter socket of output 1. Remove the short circuit from the terminals of output 1 and replace them by the 15 ohms load resistance. Increase the output voltage until the overload lamp is lit, read the current on the sub-standard meter, reduce the voltage back to zero and set the limiter current selector in turn to each of its other 5 positions. In each case increase the voltage until the limiter overload indicator is lit and check that the current lies within those limits set out in the following table. If necessary, readjust RV8 and re-check. Ensure the lamp does not light up on any range until the current indicated on the limiter switch has been exceeded. Replace the load by a short circuit and set decade switches to 20,9,1, the current registered on the internal meter should not exceed 0.5 Amps demonstrating that the proportional control transistor VT20 is operating correctly. Repeat the setting up on output No. 2, using RV3 to set the overload current limit for this output.

TABLE 2.

Limiter Setting.	Ext. Meter Reading.
1 A	1.145 - 1.265 A
500 mA	575 - 635 mA
250 mA	290 - 320 mA
100 mA	119 - 131 mA
50 mA	62 - 68 mA
25 mA	33 - 37 mA

PERFORMANCE CHECKS.

Unless otherwise stated each of the performance checks which follows must be done in turn on both supplies.

Ripple and Noise.

Set the decade voltage selectors to 20, 9, 1, set the current limiter selector to 1 Amp, connect the 500 ohms resistor across the output terminals and set it to draw a load current of 1 Amp. Adjust the Variac so that the mains voltage supply to the unit is 7% low. Connect the cathode ray oscilloscope across the output terminal and check that the ripple and noise does not exceed 2 mV peak-to-peak. Apply this check to both output channels.

REGULATION AGAINST MAINS VARIATION.

Setup the test gear as shown in Fig. 3. Set the output voltage to 20, 9, 1 and adjust the backing off supply to give a convenient reading on the Avometer, set on the 50 micro amp range. Arrange the load resistor to draw 1 Amp from the supply, vary the mains voltage from -7% to +7% of nominal. The total change in output must not exceed 5 mV.

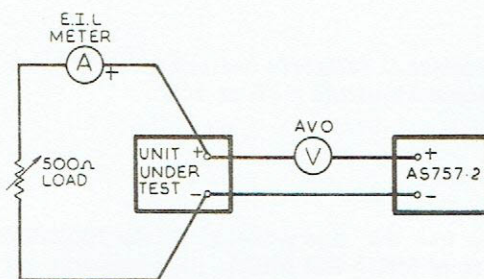


Figure 3. Regulation Test Circuit.

REGULATION AGAINST LOAD CHANGES.

With the test gear arranged as in Fig. 3, set the a.c. supply to nominal and back off the output as in the previous test. Measure the change in output voltage for a change from zero to 1 Amp load current. The change in output voltage must not exceed 30 mV.

OUTPUT IMPEDANCE.

Re-arrange the test equipment as shown in Fig. 4, and set the load current to 0.5 Amps. Set the cathode ray oscilloscope to the 10 mV/cm range, vary the oscillator frequency between 25 c/s and 100 kc/s. The display on the cathode ray oscilloscope must not exceed 15 mV peak-to-peak. Apply this check to both output channels.

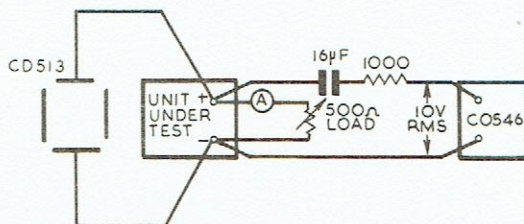


Figure 4. Impedance Test Circuit.

RECOVERY TIME.

Set up the test equipment as shown in Fig. 5. Adjust both decade switches to 10, 0, 0; set the pulse generator pulse-width to $20\mu\text{secs}$ and period to $40\mu\text{secs}$, adjust the output level to 2V, and the CRO time-base speed to $10\mu\text{secs/cm}$. Measure the recovery time of each output channel, this time must not exceed $5\mu\text{secs}$.

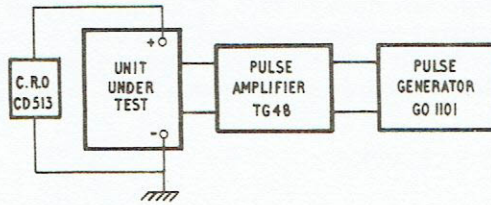


Figure 5. Recover Time Test Circuit.

METER ACCURACY.

Check the accuracy of both panel meters at fullscale deflection at current loadings of 0.2, 0.4, 0.6, 0.8 and 1.0 Amp. Panel meter accuracy should be within $\pm 3\%$ of FSD.

MISCELLANEOUS CHECKS.

Switch off the mains supply and use the Avo model 8 on the 100 ohms range, across the output terminals to measure the forward conduction of MR15 and MR16. The positive terminal of the Avo should be connected to the positive terminal of the supply. The Avo should read approximately 20 ohms.

With no load connected to the output terminals, connect the Avometer, set on the 10 mA range, across the external meter sockets at the rear of the instrument. There should be a standing current of 5 mA. Check that the red sockets are a positive polarity.

APPENDIX I.

Solartron Pulse Amplifier TG 48 used for checking the pulse response of the power supply.

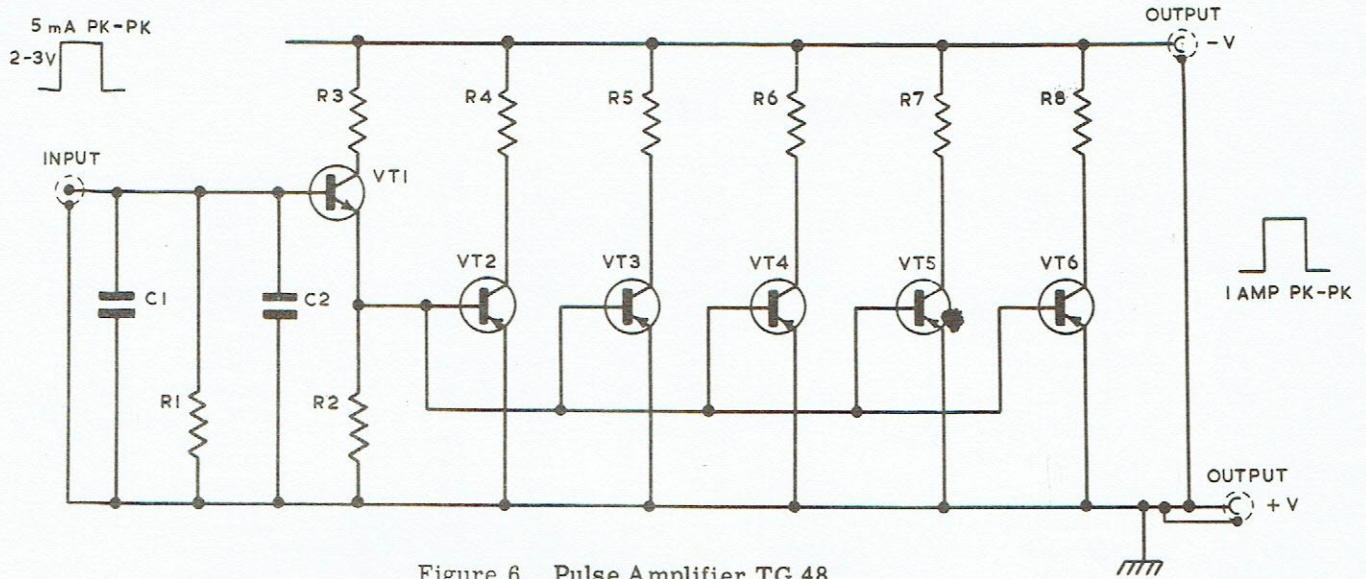


Figure 6. Pulse Amplifier TG 48.

Resistors	Capacitors	Transistors
R ₁ 1kΩ (¼ watt)	C1 - C2 0.1μF	VT1 - VT6 type TK31C
R ₂ 15Ω (¼ watt)	125V Wima	(Texas Instruments)
R ₃ -R ₈ 47Ω (2 watt)		

NOTE : All resistors must be non-inductive.

The input pulse is derived from a Solartron Pulse Generator GO 1005. The terminals XY are connected to the positive and negative terminals respectively, of the power supply under test.

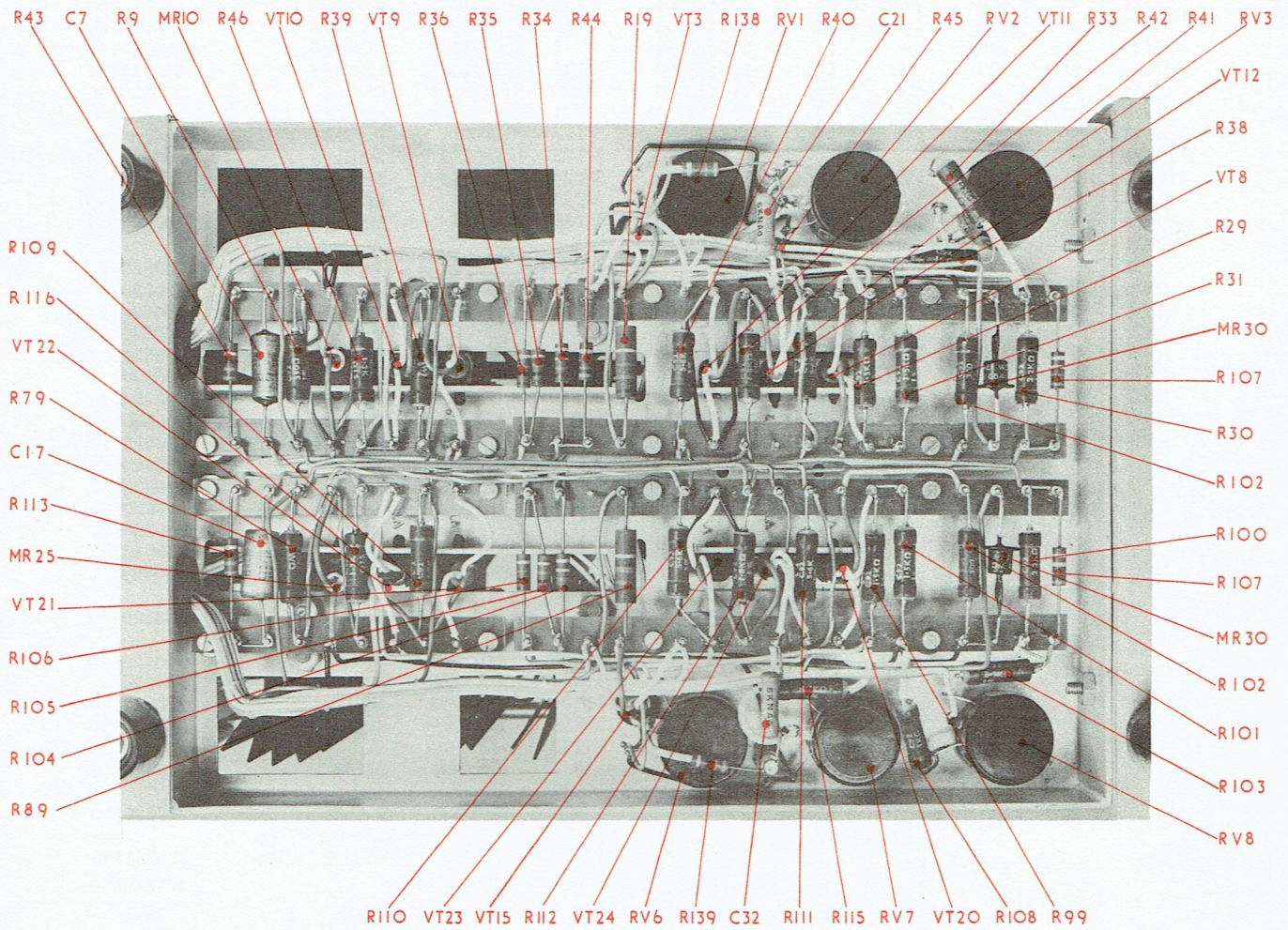
SECTION 5

COMPONENT LIST

COMPONENT PARTS LIST Abbreviations,											
Circuit References											
Component											
Cct Ref.	General Description	Solartron Part No.				Cct Ref.	General Description	Solartron Part No.			
R	Fixed Resistor (Ω)					R36	X	1000	$\frac{1}{4}$ W	10%	172331000
RV	Variable Resistor (Ω)					R37	X	22K	$\frac{1}{4}$ W	10%	172342200
C	Fixed Capacitor (μ F)					R38	W	1000	$\frac{1}{4}$ W	1%	170731000
VT	Transistor					R39	W	4700	$\frac{1}{4}$ W	5%	170834700
MR	Diode					R40	W	5600	$\frac{1}{4}$ W	5%	170835600
F	Fuse					R41	W	5600	$\frac{1}{4}$ W	5%	170835600
T	Transformer					R42	W	1800	$\frac{1}{4}$ W	5%	170831800
LP	Indicator Lamp					R43	X	68	$\frac{1}{4}$ W	10%	172316800
S	Switch					R44	X	8200	$\frac{1}{4}$ W	10%	172338200
M	Meter					R45	W	4700	$\frac{1}{4}$ W	1%	170734700
MSP	Mains Selector Panel					R46	W	1300	$\frac{1}{4}$ W	1%	170731300
TL	Terminal					R47	W	2000	$\frac{1}{4}$ W	1%	170732000
SK	Socket					R48	W	2000	$\frac{1}{4}$ W	1%	170732000
W	Resistor Composition Insulated Tolerance 5%					R49	W	200	$\frac{1}{4}$ W	1%	170422000
X	Resistor Composition Insulated Tolerance 5%					R50	W	200	$\frac{1}{4}$ W	1%	170422000
Y	Resistor, Wire Wound, Vitreous					R51	W	200	$\frac{1}{4}$ W	1%	170422000
E	Electrolytic					R52	W	200	$\frac{1}{4}$ W	1%	170422000
M. Po. Ce.	Metallised Polyester Ceramic					R53	W	200	$\frac{1}{4}$ W	1%	170422000
						R54	W	200	$\frac{1}{4}$ W	1%	170422000
						R55	W	200	$\frac{1}{4}$ W	1%	170422000
						R56	W	200	$\frac{1}{4}$ W	1%	170422000
						R57	W	200	$\frac{1}{4}$ W	1%	170422000
						R58	W	20	$\frac{1}{4}$ W	1%	170412000
						R59	W	20	$\frac{1}{4}$ W	1%	170412000
						R60	W	20	$\frac{1}{4}$ W	1%	170412000
						R61	W	20	$\frac{1}{4}$ W	1%	170412000
						R62	W	20	$\frac{1}{4}$ W	1%	170412000
						R63	W	20	$\frac{1}{4}$ W	1%	170412000
						R64	W	20	$\frac{1}{4}$ W	1%	170412000
						R65	W	20	$\frac{1}{4}$ W	1%	170412000
						R66	W	20	$\frac{1}{4}$ W	1%	170412000
						R67	W	20	$\frac{1}{4}$ W	1%	170412000
						R68	X	6800	$\frac{1}{4}$ W	10%	172336800
						R71	X	10	$\frac{1}{4}$ W	10%	172311000
						R72	X	1000	$\frac{1}{4}$ W	10%	172331000
						R73	X	220	$\frac{1}{4}$ W	10%	172322200
						R74	X	1800	$\frac{1}{4}$ W	10%	172331800
						R75	X	1000	$\frac{1}{4}$ W	10%	172331000
						R76	X	1500	$\frac{1}{4}$ W	10%	172531500
						R77	W	1200	$\frac{1}{4}$ W	1%	170431200
						R78	W	2200	$\frac{1}{4}$ W	1%	170732200
						R79	W	390	$\frac{1}{4}$ W	1%	170723900
						R80	X	4700	$\frac{1}{4}$ W	10%	172534700
						R81	X	4700	$\frac{1}{4}$ W	10%	172534700
						R82	X	1800	$\frac{1}{4}$ W	10%	172331800
						R86	W	6.3	$\frac{1}{4}$ W	1%	170706300
						R87	W	6.3	$\frac{1}{4}$ W	1%	170706300
						R88	W	6.3	$\frac{1}{4}$ W	1%	170706300
						R89	X	1500	$\frac{1}{4}$ W	10%	172531500
						R90	W	6.3	$\frac{1}{4}$ W	1%	170706300
						R91	W	6.3	$\frac{1}{4}$ W	1%	170706300
						R92	W	6.3	$\frac{1}{4}$ W	1%	170706300
						R93	W	5.1	$\frac{1}{4}$ W	1%	170405100
						R94	Y	1.17	$\frac{1}{4}$ W	2%	160200020
						R95	W	5.1	$\frac{1}{4}$ W	1%	170405100
						R96	W	7.5	$\frac{1}{4}$ W	1%	170407500
						R97	W	12	$\frac{1}{4}$ W	1%	170411200
						R98	W	20	$\frac{1}{4}$ W	1%	170412000
						R99	W	1500	$\frac{1}{4}$ W	1%	170731500
						R100	W	2200	$\frac{1}{4}$ W	1%	170732200
						R101	W	1500	$\frac{1}{4}$ W	1%	170731500
						R102	W	300	$\frac{1}{4}$ W	1%	170723000
						R103	W	3900	$\frac{1}{4}$ W	1%	170733900
						R104	X	15K	$\frac{1}{4}$ W	10%	172341500
						R105	X	1000	$\frac{1}{4}$ W	10%	172331000

R106	X	1000	$\frac{1}{4}$ W	10%	172331000	VT1	OC84	Mullard	300550270
R107	X	22K	$\frac{1}{4}$ W	10%	172342200	VT2	2G302	R. C. A.	300550400
R108	W	1000	$\frac{1}{4}$ W	1%	170731000	VT3	TK31	S. T. C.	300550350
R109	W	4700	$\frac{1}{4}$ W	5%	170834700	VT4	OC36	Mullard	300550180
R110	W	5600	$\frac{1}{4}$ W	5%	170835600	VT5	OC36	Mullard	300550180
R111	W	5600	$\frac{1}{4}$ W	5%	170835600	VT6	OC36	Mullard	300550180
R112	W	1800	$\frac{1}{4}$ W	5%	170831800	VT7	OC139	Mullard	300550280
R113	X	68	$\frac{1}{4}$ W	10%	172316800	VT8	2G302	R. C. A.	300550400
R114	X	8200	$\frac{1}{4}$ W	10%	172338200	VT9	2G302	R. C. A.	300550400
R115	W	4700	$\frac{1}{4}$ W	1%	170734700	VT10	2G302	R. C. A.	300550400
R116	W	1300	$\frac{1}{4}$ W	1%	170731300	VT11	OC139	Mullard	300550280
R117	W	2000	$\frac{1}{4}$ W	1%	170732000	VT12	OC139	Mullard	300550280
R118	W	2000	$\frac{1}{4}$ W	1%	170732000	VT13	OC84	Mullard 30	300550270
R119	W	200	$\frac{1}{4}$ W	1%	170422000	VT14	2G302	R. C. A.	300550400
R120	W	200	$\frac{1}{4}$ W	1%	170422000	VT15	TK31	S. T. G.	300550350
R121	W	200	$\frac{1}{4}$ W	1%	170422000	VT16	OC36	Mullard	300550180
R122	W	200	$\frac{1}{4}$ W	1%	170422000	VT17	OC36	Mullard	300550180
R123	W	200	$\frac{1}{4}$ W	1%	170422000	VT18	OC36	Mullard	300550180
R124	W	200	$\frac{1}{4}$ W	1%	170422000	VT19	OC139	Mullard	300550280
R125	W	200	$\frac{1}{4}$ W	1%	170422000	VT20	2G302	R. C. A.	300550400
R126	W	200	$\frac{1}{4}$ W	1%	170422000	VT21	2G302	R. C. A.	300550400
R127	W	200	$\frac{1}{4}$ W	1%	170422000	VT22	2G302	R. C. A.	300550400
R128						VT23	OC139	Mullard	300550280
to	W	20	$\frac{1}{4}$ W	1%	170412000	VT24	OC139	Mullard	300550280
R137						VT25	OC84	Mullard	300550270
R138	X	820	$\frac{1}{4}$ W	10%	172328200	VT26	OC84	Mullard	300550270
R139	X	820	$\frac{1}{4}$ W	10%	172328200				
RV1	Y	250	$\frac{1}{2}$ W	10%	110026040	MR1	IS130	Texas	300520440
RV2	Y	10k	$\frac{1}{2}$ W	10%	110026100	MR2	IS130	Texas	300520440
RV3	Y	500	$\frac{1}{2}$ W	10%	110026050	MR3	IS130	Texas	300520440
RV4	Y	250K	1/8W	20%	110001110	MR4	IS130	Texas	300520440
RV5	Y	250K	1/8W	20%	110001110	MR5	IS130	Texas	300520440
RV6	Y	250	$\frac{1}{2}$ W	10%	110026040	MR6	IS130	Texas	300520440
RV7	Y	10K	$\frac{1}{2}$ W	10%	110026100	MR7	MR33H	B. T. H.	300520580
RV8	Y	500	$\frac{1}{2}$ W	10%	110026050	MR8	OA Z203	Mullard	300520130
C1	E	250	6V	-20		MR9	OA Z203	Mullard	300520130
				+100%	260082500	MR10	ZB5.6	Brush	300520630
C2	E	2500	50V	-20		MR11	DB506	Lucas	300520590
				+50%	261192500	MR12	DB506	Lucas	300520590
C3						MR13	DB506	Lucas	300520590
C4	E	250	25V	-20		MR14	DB506	Lucas	300520590
				+100%	260782500	MR15	SJ052F	B. T. H.	300520350
C5	E	250	25V	-20		MR16			
				+100%	260782500	to	IS130	Texas	300520440
C6	E	4	150V	-20		MR21			
				+50%	261664000	MR22	MR33H	B. T. H.	300520580
C7	M. Po	0.22	125V	10%	220352200	MR23	OA Z203	Mullard	300520130
C9	E	300	50V	-20		MR24	OA Z203	Mullard	300520130
				+100%	208600030	MR25	ZB5.6	Brush	300520630
						MR26			
C10	M. Po	1	250V	20%	208700002	to	DB 506	Lucas	300520590
C11	E	250	6V	-20		MR29			
				+100%	260082500	MR30	SJ052F	B. T. H.	300520350
C12	E	2500	50V	-20		F1	2.5A	Belling & Lee	360101330
				+50%	261192500	T1	295098		301060050
C14	E	250	25V	-20		LP1		Vitality 6V	
				+100%	260782500	LP2		Vitality 6V	
C15	E	250	25V	-20		LP3		Vitality 24V	300710090
				+100%	260782500	LP4		Vitality 24V	300710090
C16	E	4	150V	-20		M1	0-1A		340001100
				+50%	261664000	M2	0-1A		340001100
C17	M. Po	0.22	125V	10%	220352200	S1		Arrow Elec	376000030
C19	E	300	50V	-20		S2		Trolex	373203050
				+100%	208600030	S3		Trolex	373310020
C20	M. Po	1	250V	20%	208200002	S4		Trolex	373106020
C21	Ce	.005	500V	-20%		S5		Trolex	373111030
				+40%	208400011	S6		Arrow Elec	376000010
C22	Ce	.005	500V	-20%		S7		Trolex	373203060
				+40%	208400011				

S8	Trox	373210030	TL3	Belling & Lee	355100180
S9	Trox	373106020	TL4	Belling & Lee	355100160
S10	Trox	373111030	TL5		355000380
S11	Arrow Elec	376000010			355000370
S12	Trox	373202010			
MSP1	Woden	399000050	SK1	Belling & Lee	352501080
TL1	Belling & Lee	355100180	SK2	Belling & Lee	352501090
TL2	Belling & Lee	355100160	SK3	Belling & Lee	352501080
			SK4	Belling & Lee	352501090



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Figure. 7. Component Location: Underside View.

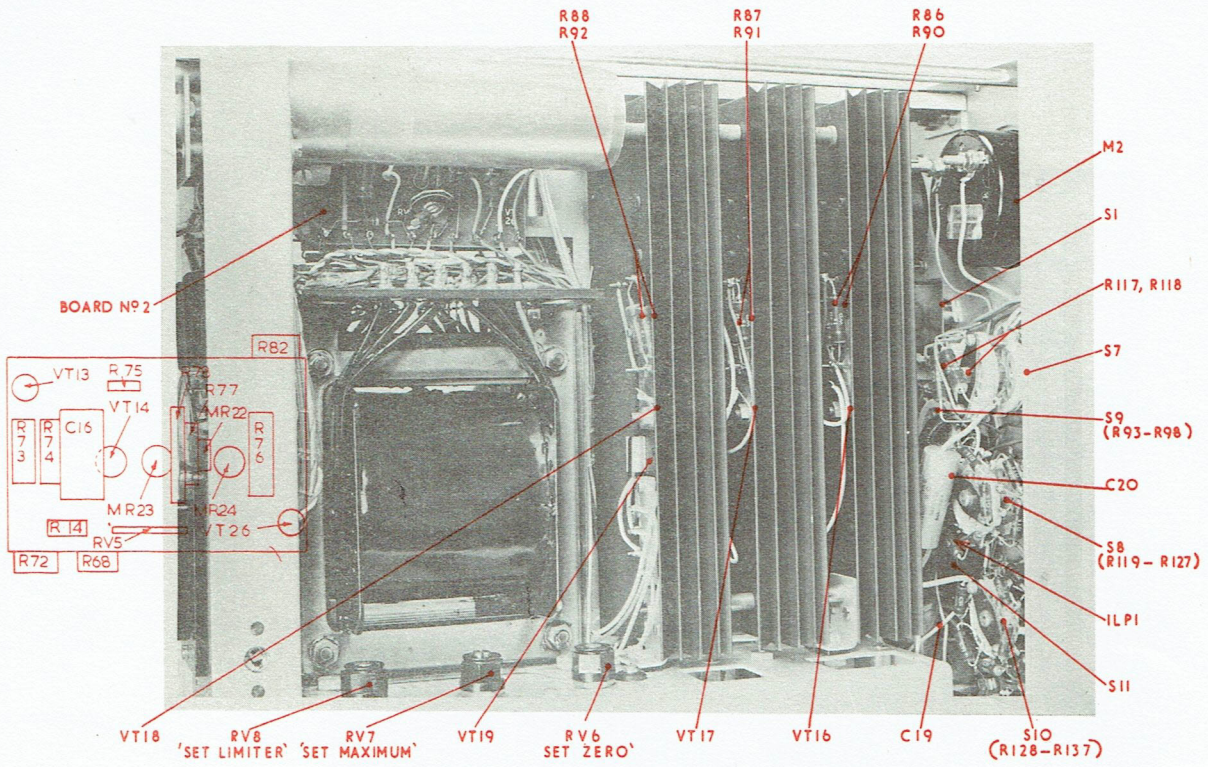


Figure 8. Component Location: Left-Hand View.

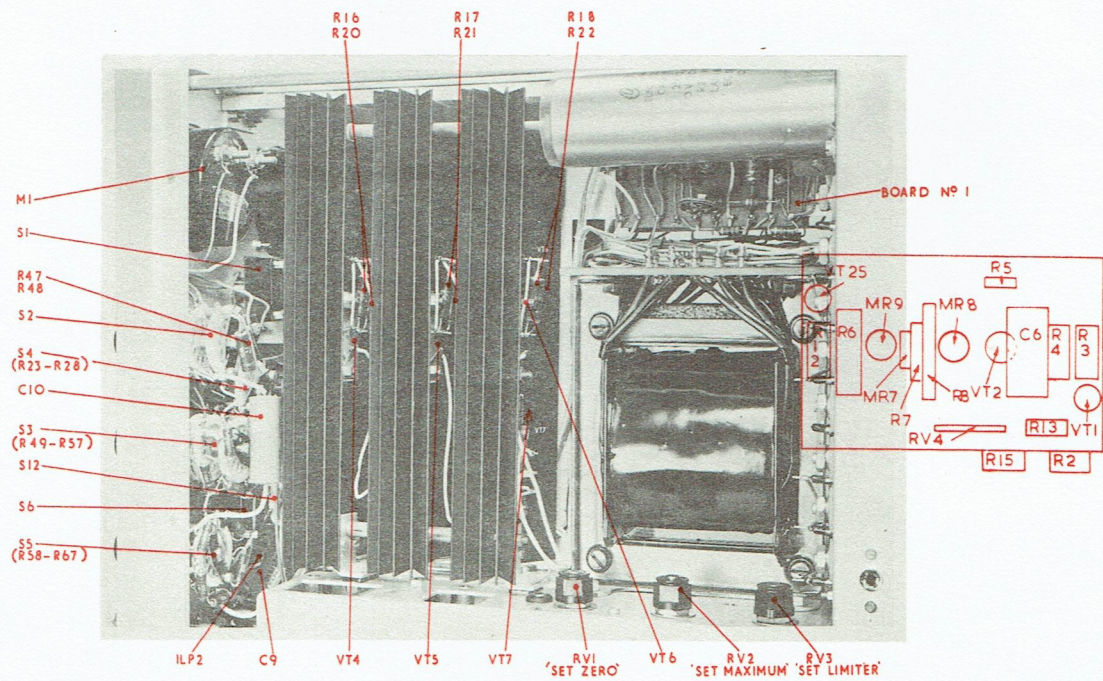


Figure 9. Component Location: Right-Hand View.

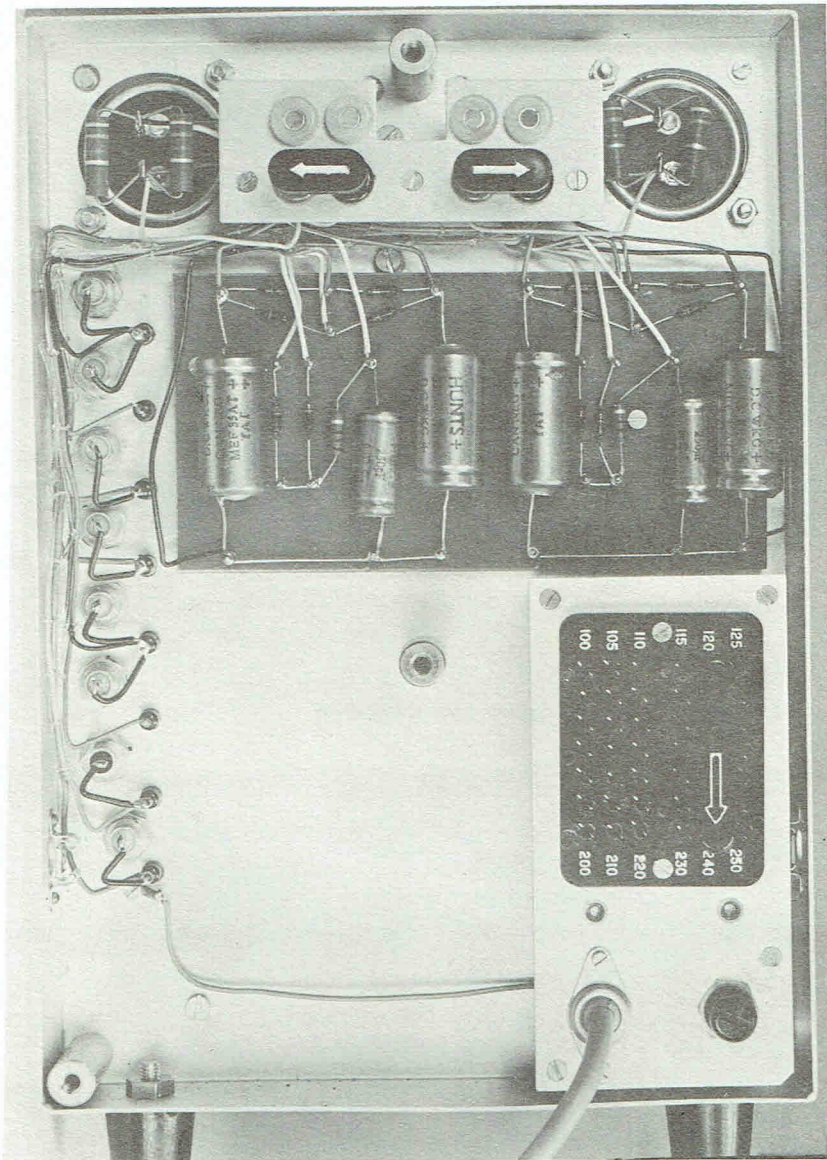


Figure 10. Component Location: Rear View.

RESISTORS	R1 R13 R14 R68	R71 R15 R73	R3 R72 R75	R2 R74	R4 R76 R77 R78	R7 R8 R79	R9 R80	R10 R81	R11 R82	R16 R83	R22 R84	R23 R85	R24 R86	R25 R87	R26 R88	R27 R89	R28 R90	R29 R91	R30 R92	R31 R93	R32 R94	R33 R95	R34 R96	R35 R97	R36 R98	R37 R99	R38 R100	R39 R101	R40 R102	R41 R103	R42 R104	R43 R105	R44 R106	R45 R107	R46 R108	R47 R109	R48 R110	R49 R111	R50 R112	R51 R113	R52 R114	R53 R115	R54 R116	R55 R117	R56 R118	R57 R119	R58 R120	R59 R121	R60 R122	R61 R123	R62 R124	R63 R125	R64 R126	R65 R127	R66 R128	R67 R129	R68 R130	R69 R131	R70 R132	R71 R133	R72 R134	R73 R135	R74 R136	R75 R137	R76 R138	R77 R139	R78 R140	R79 R141	R80 R142	R81 R143	R82 R144	R83 R145	R84 R146	R85 R147	R86 R148	R87 R149	R88 R150	R89 R151	R90 R152	R91 R153	R92 R154	R93 R155	R94 R156	R95 R157	R96 R158	R97 R159	R98 R160	R99 R161	R100 R162	R101 R163	R102 R164	R103 R165	R104 R166	R105 R167	R106 R168	R107 R169	R108 R170	R109 R171	R110 R172	R111 R173	R112 R174	R113 R175	R114 R176	R115 R177	R116 R178	R117 R179	R118 R180	R119 R181	R120 R182	R121 R183	R122 R184	R123 R185	R124 R186	R125 R187	R126 R188	R127 R189	R128 R190	R129 R191	R130 R192	R131 R193	R132 R194	R133 R195	R134 R196	R135 R197	R136 R198	R137 R199	R138 R200	R139 R201	R140 R202	R141 R203	R142 R204	R143 R205	R144 R206	R145 R207	R146 R208	R147 R209	R148 R210	R149 R211	R150 R212	R151 R213	R152 R214	R153 R215	R154 R216	R155 R217	R156 R218	R157 R219	R158 R220	R159 R221	R160 R222	R161 R223	R162 R224	R163 R225	R164 R226	R165 R227	R166 R228	R167 R229	R168 R230	R169 R231	R170 R232	R171 R233	R172 R234	R173 R235	R174 R236	R175 R237	R176 R238	R177 R239	R178 R240	R179 R241	R180 R242	R181 R243	R182 R244	R183 R245	R184 R246	R185 R247	R186 R248	R187 R249	R188 R250	R189 R251	R190 R252	R191 R253	R192 R254	R193 R255	R194 R256	R195 R257	R196 R258	R197 R259	R198 R260	R199 R261	R200 R262	R201 R263	R202 R264	R203 R265	R204 R266	R205 R267	R206 R268	R207 R269	R208 R270	R209 R271	R210 R272	R211 R273	R212 R274	R213 R275	R214 R276	R215 R277	R216 R278	R217 R279	R218 R280	R219 R281	R220 R282	R221 R283	R222 R284	R223 R285	R224 R286	R225 R287	R226 R288	R227 R289	R228 R290	R229 R291	R230 R292	R231 R293	R232 R294	R233 R295	R234 R296	R235 R297	R236 R298	R237 R299	R238 R300	R239 R301	R240 R302	R241 R303	R242 R304	R243 R305	R244 R306	R245 R307	R246 R308	R247 R309	R248 R310	R249 R311	R250 R312	R251 R313	R252 R314	R253 R315	R254 R316	R255 R317	R256 R318	R257 R319	R258 R320	R259 R321	R260 R322	R261 R323	R262 R324	R263 R325	R264 R326	R265 R327	R266 R328	R267 R329	R268 R330	R269 R331	R270 R332	R271 R333	R272 R334	R273 R335	R274 R336	R275 R337	R276 R338	R277 R339	R278 R340	R279 R341	R280 R342	R281 R343	R282 R344	R283 R345	R284 R346	R285 R347	R286 R348	R287 R349	R288 R350	R289 R351	R290 R352	R291 R353	R292 R354	R293 R355	R294 R356	R295 R357	R296 R358	R297 R359	R298 R360	R299 R361	R300 R362	R301 R363	R302 R364	R303 R365	R304 R366	R305 R367	R306 R368	R307 R369	R308 R370	R309 R371	R310 R372	R311 R373	R312 R374	R313 R375	R314 R376	R315 R377	R316 R378	R317 R379	R318 R380	R319 R381	R320 R382	R321 R383	R322 R384	R323 R385	R324 R386	R325 R387	R326 R388	R327 R389	R328 R390	R329 R391	R330 R392	R331 R393	R332 R394	R333 R395	R334 R396	R335 R397	R336 R398	R337 R399	R338 R400	R339 R401	R340 R402	R341 R403	R342 R404	R343 R405	R344 R406	R345 R407	R346 R408	R347 R409	R348 R410	R349 R411	R350 R412	R351 R413	R352 R414	R353 R415	R354 R416	R355 R417	R356 R418	R357 R419	R358 R420	R359 R421	R360 R422	R361 R423	R362 R424	R363 R425	R364 R426	R365 R427	R366 R428	R367 R429	R368 R430	R369 R431	R370 R432	R371 R433	R372 R434	R373 R435	R374 R436	R375 R437	R376 R438	R377 R439	R378 R440	R379 R441	R380 R442	R381 R443	R382 R444	R383 R445	R384 R446	R385 R447	R386 R448	R387 R449	R388 R450	R389 R451	R390 R452	R391 R453	R392 R454	R393 R455	R394 R456	R395 R457	R396 R458	R397 R459	R398 R460	R399 R461	R400 R462	R401 R463	R402 R464	R403 R465	R404 R466	R405 R467	R406 R468	R407 R469	R408 R470	R409 R471	R410 R472	R411 R473	R412 R474	R413 R475	R414 R476	R415 R477	R416 R478	R417 R479	R418 R480	R419 R481	R420 R482	R421 R483	R422 R484	R423 R485	R424 R486	R425 R487	R426 R488	R427 R489	R428 R490	R429 R491	R430 R492	R431 R493	R432 R494	R433 R495	R434 R496	R435 R497	R436 R498	R437 R499	R438 R500	R439 R501	R440 R502	R441 R503	R442 R504	R443 R505	R444 R506	R445 R507	R446 R508	R447 R509	R448 R510	R449 R511	R450 R512	R451 R513	R452 R514	R453 R515	R454 R516	R455 R517	R456 R518	R457 R519	R458 R520	R459 R521	R460 R522	R461 R523	R462 R524	R463 R525	R464 R526	R465 R527	R466 R528	R467 R529	R468 R530	R469 R531	R470 R532	R471 R533	R472 R534	R473 R535	R474 R536	R475 R537	R476 R538	R477 R539	R478 R540	R479 R541	R480 R542	R481 R543	R482 R544	R483 R545	R484 R546	R485 R547	R486 R548	R487 R549	R488 R550	R489 R551	R490 R552	R491 R553	R492 R554	R493 R555	R494 R556	R495 R557	R496 R558	R497 R559	R498 R560	R499 R561	R500 R562	R501 R563	R502 R564	R503 R565	R504 R566	R505 R567	R506 R568	R507 R569	R508 R570	R509 R571	R510 R572	R511 R573	R512 R574	R513 R575	R514 R576	R515 R577	R516 R578	R517 R579	R518 R580	R519 R581	R520 R582	R521 R583	R522 R584	R523 R585	R524 R586	R525 R587	R526 R588	R527 R589	R528 R590	R529 R591	R530 R592	R531 R593	R532 R594	R533 R595	R534 R596	R535 R597	R536 R598	R537 R599	R538 R600	R539 R601	R540 R602	R541 R603	R542 R604	R543 R605	R544 R606	R545 R607	R546 R608	R547 R609	R548 R610	R549 R611	R550 R612	R551 R613	R552 R614	R553 R615	R554 R616	R555 R617	R556 R618	R557 R619	R558 R620	R559 R621	R560 R622	R561 R623	R562 R624	R563 R625	R564 R626	R565 R627	R566 R628	R567 R629	R568 R630	R569 R631	R570 R632	R571 R633	R572 R634	R573 R635	R574 R636	R575 R637	R576 R638	R577 R639	R578 R640	R579 R641	R580 R642	R581 R643	R582 R644	R583 R645	R584 R646	R585 R647	R586 R648	R587 R649	R588 R650	R589 R651	R590 R652	R591 R653	R592 R654	R593 R655	R594 R656	R595 R657	R596 R658	R597 R659	R598 R660	R599 R661	R600 R662	R601 R663	R602 R664	R603 R665	R604 R666	R605 R667	R606 R668	R607 R669	R608 R670	R609 R671	R610 R672	R611 R673	R612 R674	R613 R675	R614 R676	R615 R677	R616 R678	R617 R679	R618 R680	R619 R681	R620 R682	R621 R683	R622 R684	R623 R685	R624 R686	R625 R687	R626 R688	R627 R689	R628 R690	R629 R691	R630 R692	R631 R693	R632 R694	R633 R695	R634 R696	R635 R697	R636 R698	R637 R699	R638 R700	R639 R701	R640 R702	R641 R703	R642 R704	R643 R705	R644 R706	R645 R707	R646 R708	R647 R709	R648 R710	R649 R711	R650 R712	R651 R713	R652 R714	R653 R715	R654 R716	R655 R717	R656 R718	R657 R719	R658 R720	R659 R721	R660 R722	R661 R723	R662 R724	R663 R725	R664 R726	R665 R727	R666 R728	R667 R729	R668 R730	R669 R731	R670 R732	R671 R733	R672 R734	R673 R735	R674 R736	R675 R737	R676 R738	R677 R739	R678 R740	R679 R741	R680 R742	R681 R743	R682 R744	R683 R745	R684 R746	R685 R747	R686 R748	R687 R749	R688 R750	R689 R751	R690 R752	R691 R753	R692 R754	R693 R755	R694 R756	R695 R757	R696 R758	R697 R759	R698 R760	R699 R761	R700 R762	R701 R763	R702 R764	R703 R765	R704 R766	R705 R767	R706 R768	R707 R769	R708 R770	R709 R771	R710 R772	R711 R773	R712 R774	R713 R775	R714 R776	R715 R777	R716 R778	R717 R779	R718 R780	R719 R781	R720 R782	R721 R783	R722 R784	R723 R785	R724 R786	R725 R787	R726 R788	R727 R789	R728 R790	R729 R791	R730 R792	R731 R793	R732 R794	R733 R795	R734 R796	R735 R797	R736 R798	R737 R799	R738 R800	R739 R801	R740 R802	R741 R803	R742 R804	R743 R805	R744 R806	R745 R807	R746 R808	R747 R809	R748 R810	R749 R811	R750 R812	R751 R813	R752 R814	R753 R815	R754 R816	R755 R817	R756 R818	R757 R819	R758 R820	R759 R821	R760 R822	R761 R823	R762 R824	R763 R825	R764 R826	R765 R827	R766 R828	R767 R829	R768 R830	R769 R831	R770 R832	R771 R833	R772 R834	R773 R835	R774 R836	R775 R837	R776 R838	R777 R839	R778 R840	R779 R841	R780 R842	R781 R843	R782 R844	R783 R845	R784 R846	R785 R847	R786 R848	R787 R849	R788 R850	R789 R851	R790 R852	R791 R853	R792 R854	R793 R855	R794 R856	R795 R857	R796 R858	R797 R859	R798 R860	R799 R861	R800 R862	R801 R863	R802 R864	R803 R865	R804 R866	R805 R867	R806 R868	R807 R869	R808 R870	R809 R871	R810 R872	R811 R873	R812 R874	R813 R875	R814 R876	R815 R877	R816 R878	R817 R879	R818 R880	R819 R881	R820 R882	R821 R883	R822 R884	R823 R885	R824 R886	R825 R887	R826 R888	R827 R889	R828 R890	R829 R891	R830 R892	R831 R893	R832 R894	R833 R895	R834 R896	R835 R897	R836 R898	R837 R899	R838 R900	R839 R901
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**THE SOLARTRON ELECTRONIC GROUP LTD.
FARNBOROUGH • HAMPSHIRE • ENGLAND**

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