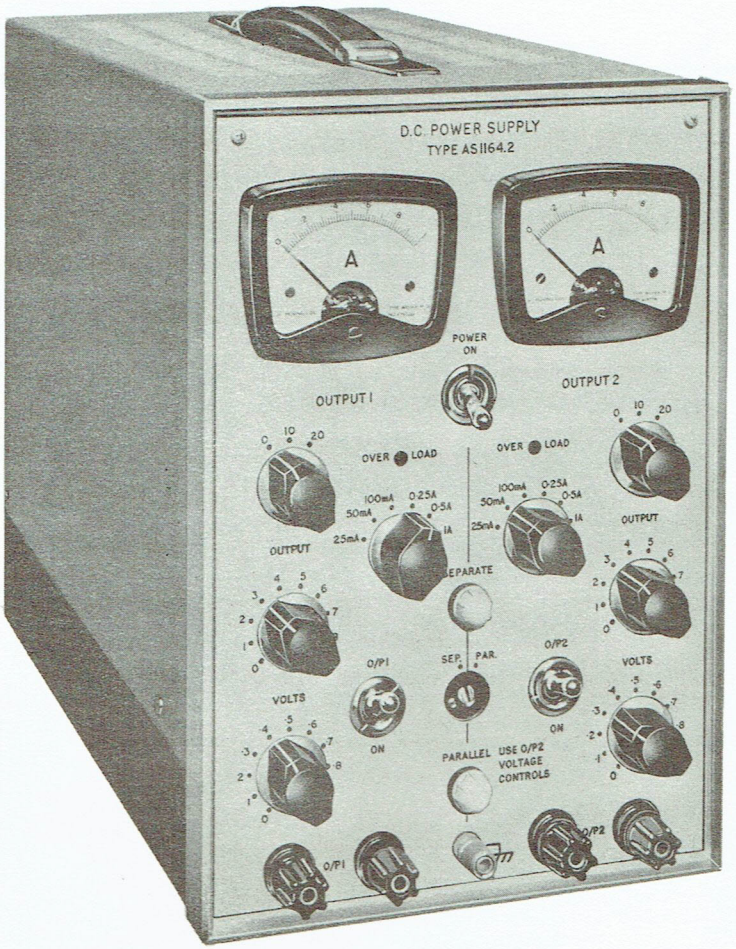
643

TWIN TRANSISTOR POWER SUPPLY AS 1164.2

SOLARTRON

TECHNICAL MANUAL

TWIN TRANSISTOR POWER SUPPLY AS 1164.2



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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 ± 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 ± 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.

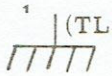
An indicator lamp which is lit when the two supplies are set for parallel operation.

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.



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.

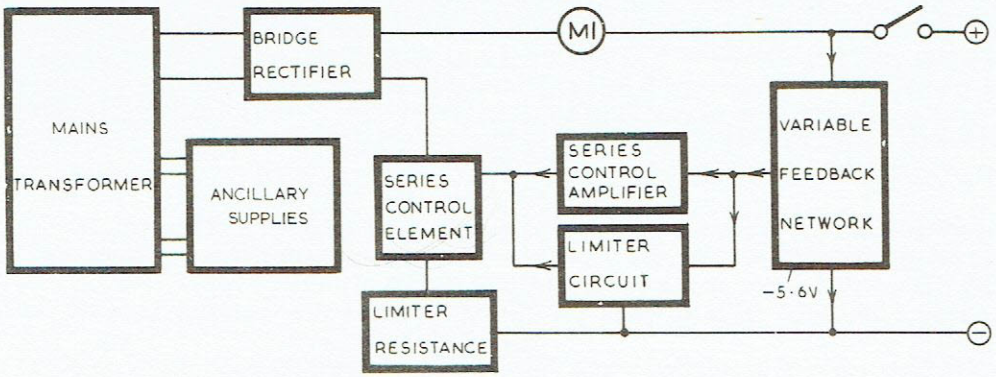


Figure 1. Block Diagram AS1164.2

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.

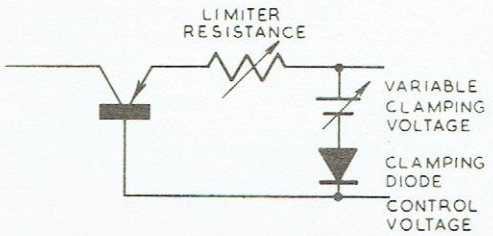


Figure 2. Simplified overload Control System.

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 unstabilised 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 inadvertantly 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 ± 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.

Set up 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.

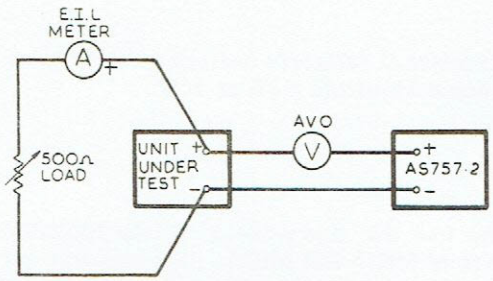


Figure 3. Regulation Test Circuit.

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.

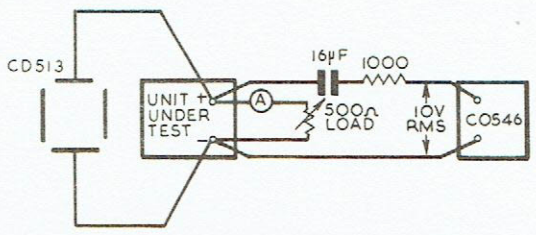


Figure 4. Impedance Test Circuit.

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 20μsecs and period to 40μsecs, adjust the output level to 2V, and the CRO time-base speed to 10μsecs/cm. Measure the recovery time of each output channel, this time must not exceed 5μsecs.

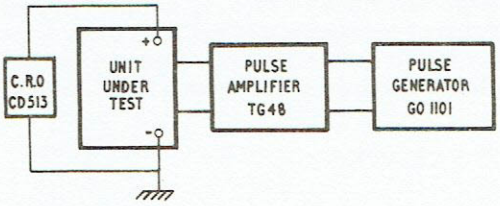


Figure 5. Recover Time Test Circuit.

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 ± 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.

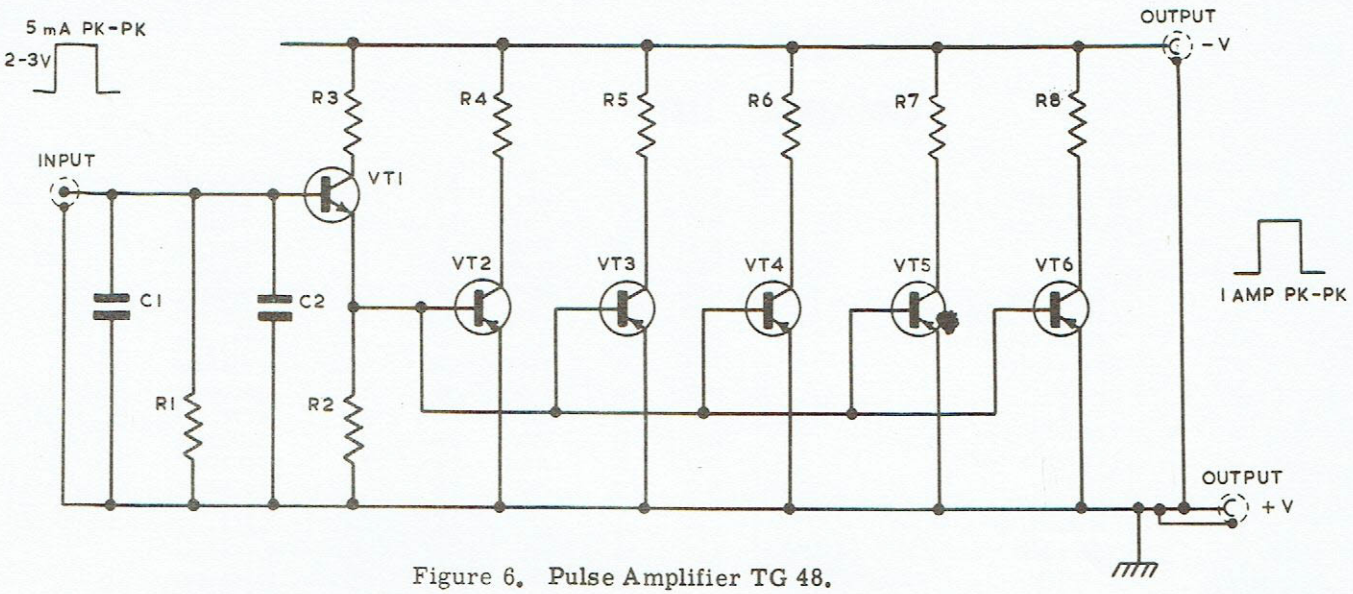


Figure 6. Pulse Amplifier TG 48.

Resistors		Capacitors	Transistors
R_1	1kΩ ($\frac{1}{4}$ watt)	C1 - C2 0.1μF	VT1 - VT6 type TK31C (Texas Instruments)
R_2	15Ω ($\frac{1}{4}$ watt)	125V Wima	
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

R	Fixed Resistor (Ω)
RV	Variable Resistor(Ω)
C	Fixed Capacitor (μF)
VT	Transistor
MR	Diode
F	Fuse
T	Transformer
LP	Indicator Lamp
S	Switch
M	Meter
MSP	Mains Selector Panel
TL	Terminal
SK	Socket

Component

W	Resistor Composition Insulated Tolerance 5%
X	Resistor Composition Insulated Tolerance 5%
Y	Resistor, Wire Wound, Vitreous
E	Electrolytic
M. Po.	Metallised Polyester
Ce.	Ceramic

Cct Ref.	General Description				Solartron Part No.
R1	X	10	¼W	10%	172311000
R2	X	1000	¼W	10%	172331000
R3	X	220	¼W	10%	172322200
R4	X	1800	¼W	10%	172331800
R5	X	1000	¼W	10%	172331000
R6	X	1500	½W	10%	172531500
R7	W	1200	¼W	1%	170431200
R8	W	2200	½W	1%	170732200
R9	W	390	½W	1%	170723900
R10	X	4700	½W	10%	172534700
R11	X	4700	½W	10%	172534700
R12	X	1800	¼W	10%	172331800
R13	X	18K	¼W	10%	172341800
R14	X	18K	¼W	10%	172341800
R15	X	6800	¼W	10%	172336800
R16	W	6.3	½W	1%	170706300
R17	W	6.3	½W	1%	170706300
R18	W	6.3	½W	1%	170706300
R19	X	1500	½W	10%	172531500
R20	W	6.3	½W	1%	170706300
R21	W	6.3	½W	1%	170706300
R22	W	6.3	½W	1%	170706300
R23	W	5.1	¼W	1%	170405100
R24	Y	1.17		2%	160200020
R25	W	5.1	¼W	1%	170405100
R26	W	7.5	¼W	1%	170407500
R27	W	12	¼W	1%	170411200
R28	W	20	¼W	1%	170412000
R29	W	1500	½W	1%	170731500
R30	W	2200	½W	1%	170732200
R31	W	1500	½W	1%	170731500
R32	W	300	½W	1%	170723000
R33	W	3900	½W	1%	170733900
R34	X	15K	¼W	10%	172341500
R35	X	1000	¼W	10%	172331000
R36	X	1000	¼W	10%	172331000
R37	X	22K	¼W	10%	172342200
R38	W	1000	½W	1%	170731000
R39	W	4700	½W	5%	170834700
R40	W	5600	½W	5%	170835600
R41	W	5600	½W	5%	170835600
R42	W	1800	½W	5%	170831800
R43	X	68	¼W	10%	172316800
R44	X	8200	¼W	10%	172338200
R45	W	4700	½W	1%	170734700
R46	W	1300	½W	1%	170731300
R47	W	2000	½W	1%	170732000
R48	W	2000	½W	1%	170732000
R49	W	200	¼W	1%	170422000
R50	W	200	¼W	1%	170422000
R51	W	200	¼W	1%	170422000
R52	W	200	¼W	1%	170422000
R53	W	200	¼W	1%	170422000
R54	W	200	¼W	1%	170422000
R55	W	200	¼W	1%	170422000
R56	W	200	¼W	1%	170422000
R57	W	200	¼W	1%	170422000
R58	W	20	¼W	1%	170412000
R59	W	20	¼W	1%	170412000
R60	W	20	¼W	1%	170412000
R61	W	20	¼W	1%	170412000
R62	W	20	¼W	1%	170412000
R63	W	20	¼W	1%	170412000
R64	W	20	¼W	1%	170412000
R65	W	20	¼W	1%	170412000
R66	W	20	¼W	1%	170412000
R67	W	20	¼W	1%	170412000
R68	X	6800	¼W	10%	172336800
R71	X	10	¼W	10%	172311000
R72	X	1000	¼W	10%	172331000
R73	X	220	¼W	10%	172322200
R74	X	1800	¼W	10%	172331800
R75	X	1000	¼W	10%	172331000
R76	X	1500	½W	10%	172531500
R77	W	1200	¼W	1%	170431200
R78	W	2200	½W	1%	170732200
R79	W	390	½W	1%	170723900
R80	X	4700	½W	10%	172534700
R81	X	4700	½W	10%	172534700
R82	X	1800	¼W	10%	172331800
R86	W	6.3	½W	1%	170706300
R87	W	6.3	½W	1%	170706300
R88	W	6.3	½W	1%	170706300
R89	X	1500	½W	10%	172531500
R90	W	6.3	½W	1%	170706300
R91	W	6.3	½W	1%	170706300
R92	W	6.3	½W	1%	170706300
R93	W	5.1	¼W	1%	170405100
R94	Y	1.17		2%	160200020
R95	W	5.1	¼W	1%	170405100
R96	W	7.5	¼W	1%	170407500
R97	W	12	¼W	1%	170411200
R98	W	20	¼W	1%	170412000
R99	W	1500	½W	1%	170731500
R100	W	2200	½W	1%	170732200
R101	W	1500	½W	1%	170731500
R102	W	300	½W	1%	170723000
R103	W	3900	½W	1%	170733900
R104	X	15K	¼W	10%	172341500
R105	X	1000	¼W	10%	172331000

R106	X	1000	¼W	10%	172331000
R107	X	22K	¼W	10%	172342200
R108	W	1000	½W	1%	170731000
R109	W	4700	½W	5%	170834700
R110	W	5600	½W	5%	170835600
R111	W	5600	½W	5%	170835600
R112	W	1800	½W	5%	170831800
R113	X	68	¼W	10%	172316800
R114	X	8200	¼W	10%	172338200
R115	W	4700	½W	1%	170734700
R116	W	1300	½W	1%	170731300
R117	W	2000	½W	1%	170732000
R118	W	2000	½W	1%	170732000
R119	W	200	¼W	1%	170422000
R120	W	200	¼W	1%	170422000
R121	W	200	¼W	1%	170422000
R122	W	200	¼W	1%	170422000
R123	W	200	¼W	1%	170422000
R124	W	200	¼W	1%	170422000
R125	W	200	¼W	1%	170422000
R126	W	200	¼W	1%	170422000
R127	W	200	¼W	1%	170422000
R128 to R137	W	20	¼W	1%	170412000
R138	X	820	¼W	10%	172328200
R139	X	820	¼W	10%	172328200
RV1	Y	250	½W	10%	110026040
RV2	Y	10k	½W	10%	110026100
RV3	Y	500	½W	10%	110026050
RV4	Y	250K	1/8W	20%	110001110
RV5	Y	250K	1/8W	20%	110001110
RV6	Y	250	½W	10%	110026040
RV7	Y	10K	½W	10%	110026100
RV8	Y	500	½W	10%	110026050
C1	E	250	6V	-20 +100%	260082500
C2	E	2500	50V	-20 +50%	261192500
C3					
C4	E	250	25V	-20 +100%	260782500
C5	E	250	25V	-20 +100%	260782500
C6	E	4	150V	-20 +50%	261664000
C7	M.Po	0.22	125V	10%	220352200
C9	E	300	50V	-20 +100%	208600030
C10	M.Po	1	250V	20%	208700002
C11	E	250	6V	-20 +100%	260082500
C12	E	2500	50V	-20 +50%	261192500
C14	E	250	25V	-20 +100%	260782500
C15	E	250	25V	-20 +100%	260782500
C16	E	4	150V	-20 +50%	261664000
C17	M.Po	0.22	125V	10%	220352200
C19	E	300	50V	-20 +100%	208600030
C20	M.Po	1	250V	20%	208200002
C21	Ce	.005	500V	-20% +40%	208400011
C22	Ce	.005	500V	-20% +40%	208400011

VT1	OC84	Mullard	300550270
VT2	2G302	R.C.A.	300550400
VT3	TK31	S.T.C.	300550350
VT4	OC36	Mullard	300550180
VT5	OC36	Mullard	300550180
VT6	OC36	Mullard	300550180
VT7	OC139	Mullard	300550280
VT8	2G302	R.C.A.	300550400
VT9	2G302	R.C.A.	300550400
VT10	2G302	R.C.A.	300550400
VT11	OC139	Mullard	300550280
VT12	OC139	Mullard	300550280
VT13	OC84	Mullard 30	300550270
VT14	2G302	R.C.A.	300550400
VT15	TK31	S.T.G.	300550350
VT16	OC36	Mullard	300550180
VT17	OC36	Mullard	300550180
VT18	OC36	Mullard	300550180
VT19	OC139	Mullard	300550280
VT20	2G302	R.C.A.	300550400
VT21	2G302	R.C.A.	300550400
VT22	2G302	R.C.A.	300550400
VT23	OC139	Mullard	300550280
VT24	OC139	Mullard	300550280
VT25	OC84	Mullard	300550270
VT26	OC84	Mullard	300550270
MR1	IS130	Texas	300520440
MR2	IS130	Texas	300520440
MR3	IS130	Texas	300520440
MR4	IS130	Texas	300520440
MR5	IS130	Texas	300520440
MR6	IS130	Texas	300520440
MR7	MR33H	B.T.H.	300520580
MR8	OAZ203	Mullard	300520130
MR9	OAZ203	Mullard	300520130
MR10	ZB5.6	Brush	300520630
MR11	DB506	Lucas	300520590
MR12	DB506	Lucas	300520590
MR13	DB506	Lucas	300520590
MR14	DB506	Lucas	300520590
MR15	SJ052F	B.T.H.	300520350
MR16 to MR21	IS130	Texas	300520440
MR22	MR33H	B.T.H.	300520580
MR23	OAZ203	Mullard	300520130
MR24	OAZ203	Mullard	300520130
MR25	ZB5.6	Brush	300520630
MR26 to MR29	DB 506	Lucas	300520590
MR30	SJ052F	B.T.H.	300520350
F1	2.5A	Belling & Lee	360101330
T1	295098		301060050
LP1		Vitality 6V	
LP2		Vitality 6V	
LP3		Vitality 24V	300710090
LP4		Vitality 24V	300710090
M1	0-1A		340001100
M2	0-1A		340001100
S1		Arrow Elec	376000030
S2		Trolex	373203050
S3		Trolex	373310020
S4		Trolex	373106020
S5		Trolex	373111030
S6		Arrow Elec	376000010
S7		Trolex	373203060

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

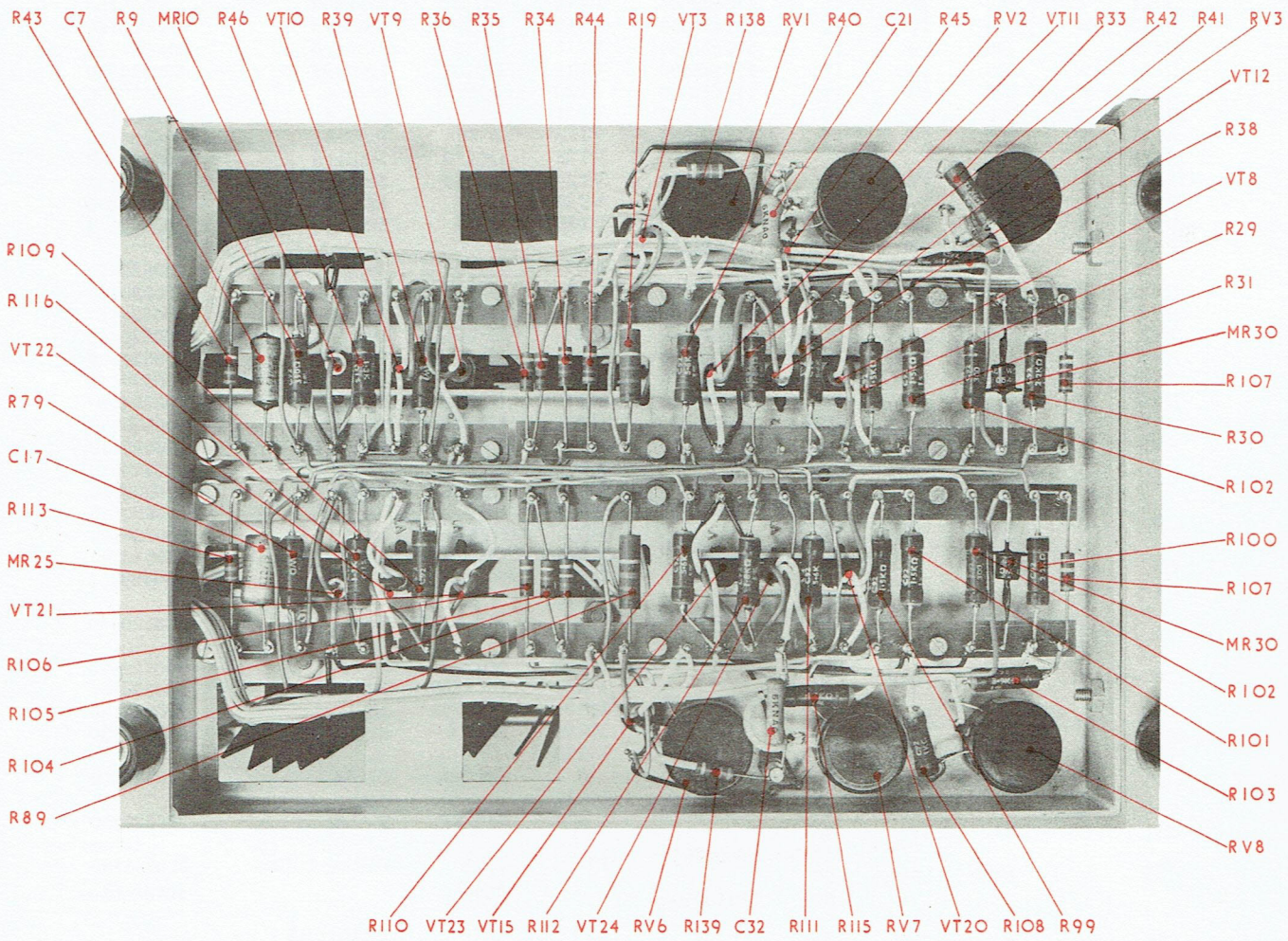


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Figure. 7. Component Location: Underside View.

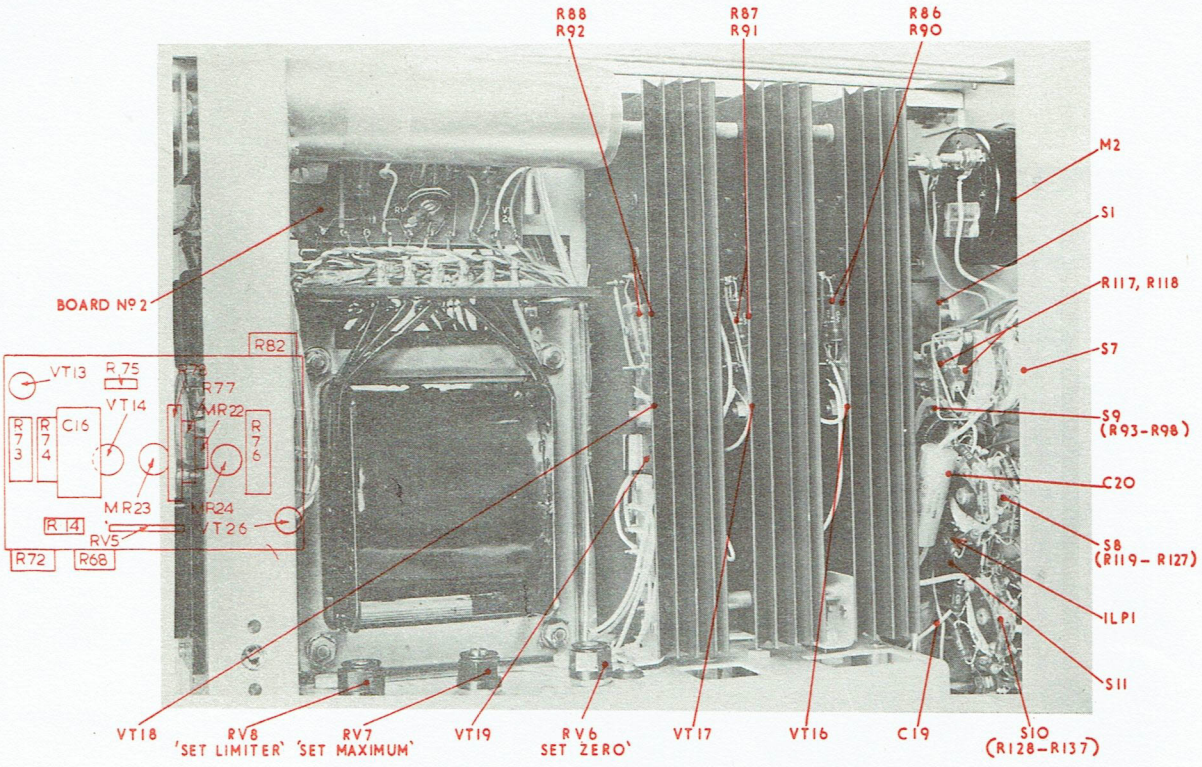

Figure 8. Component Location: Left-Hand View.

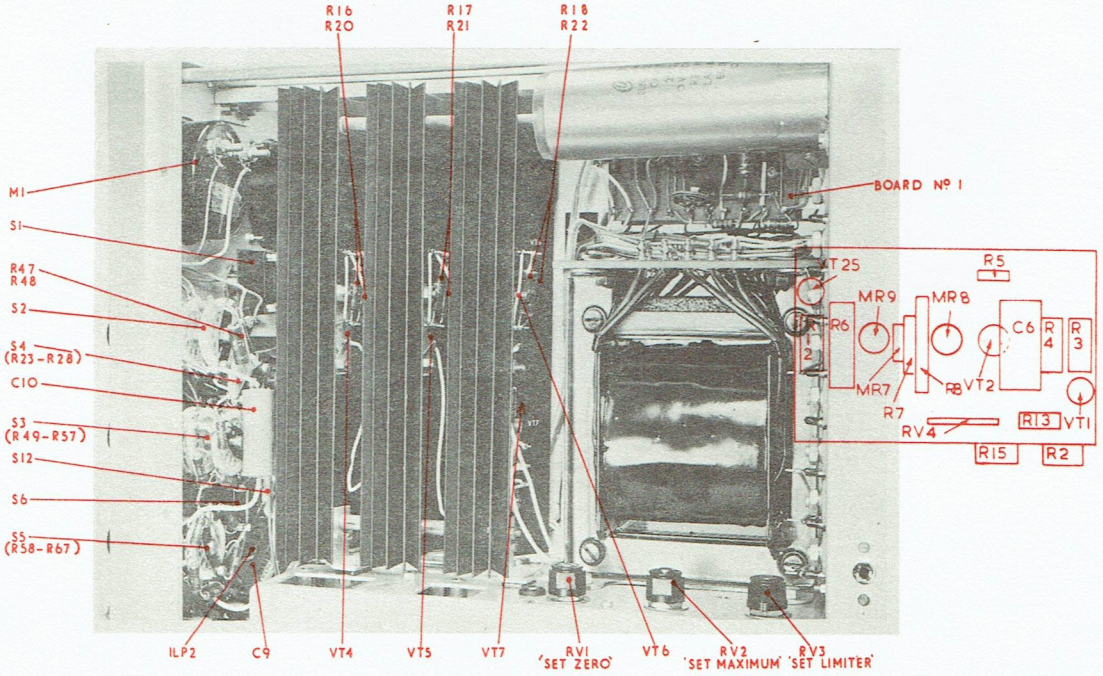

Figure 9. Component Location: Right-Hand View.

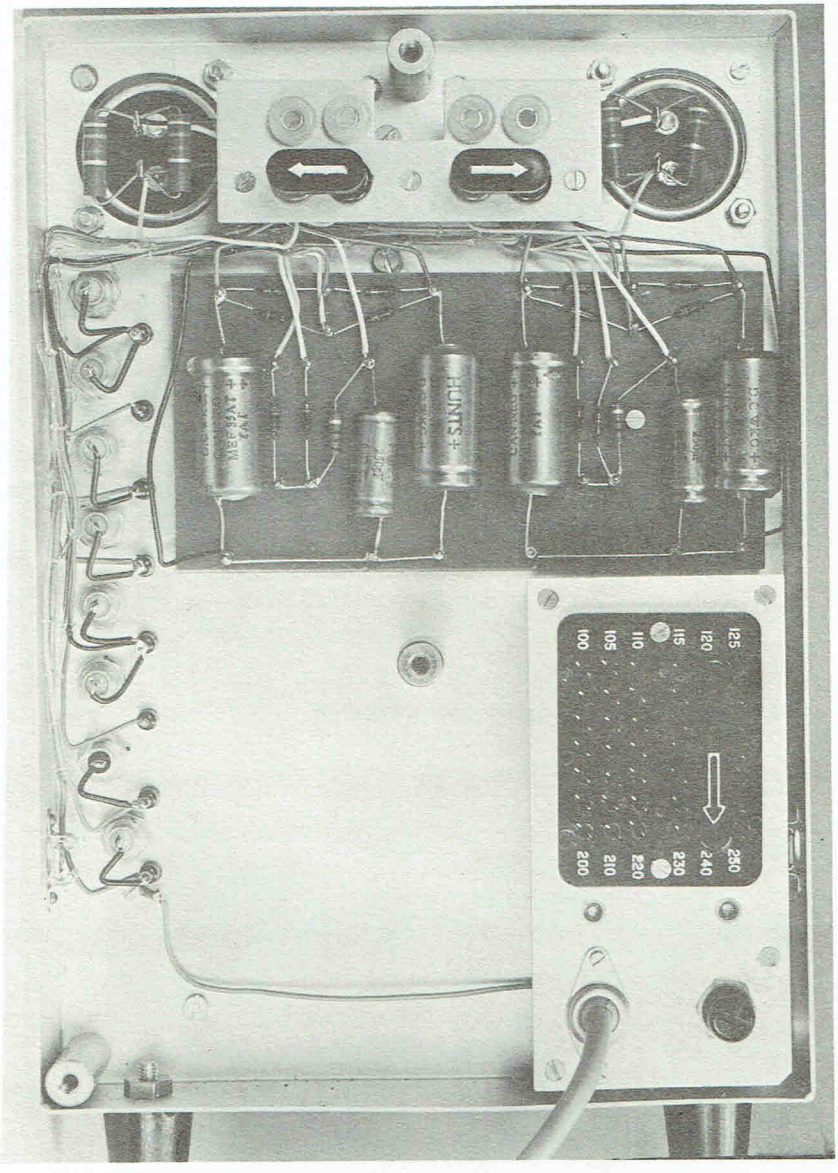

Figure 10. Component Location: Rear View.

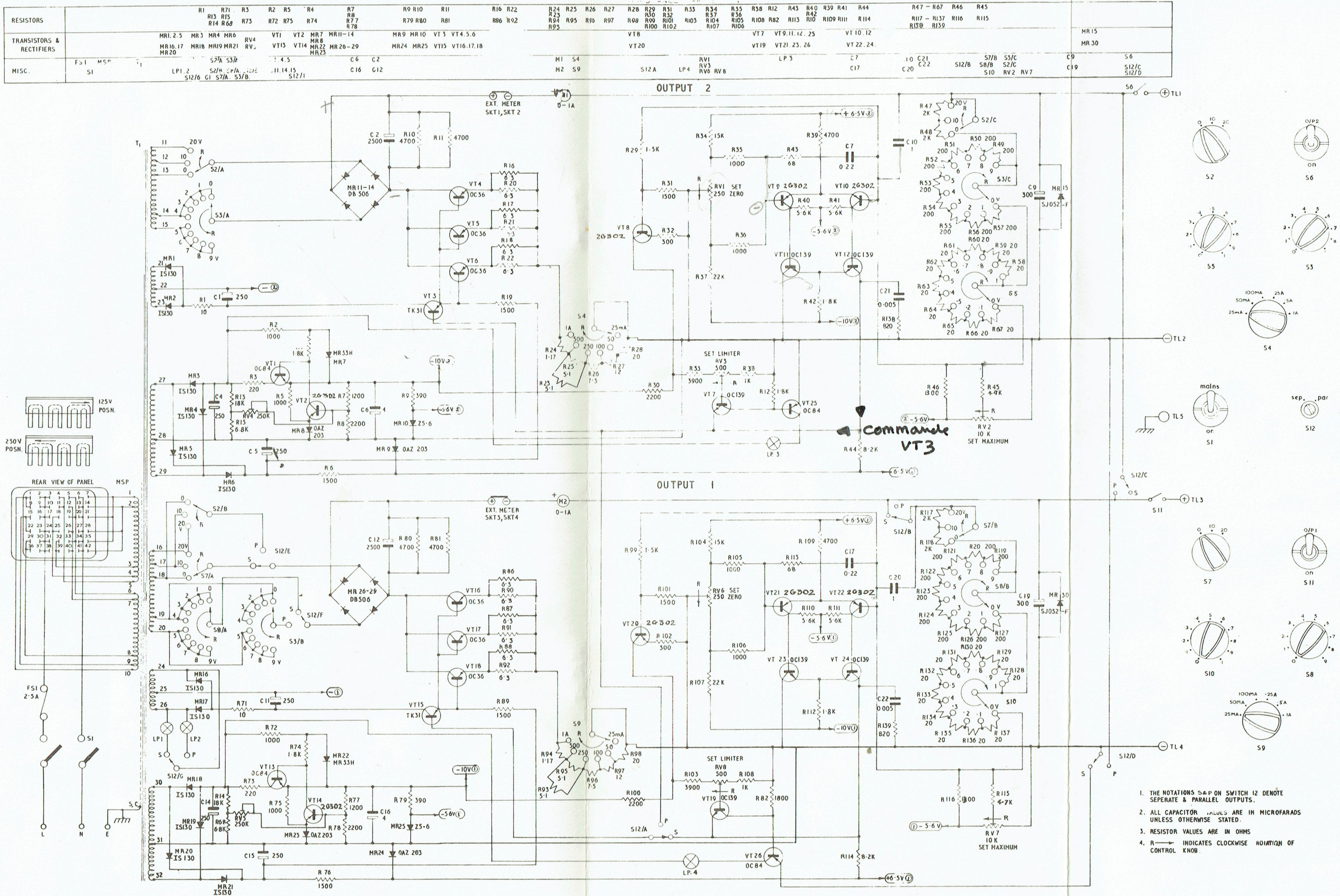

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Fig. 11. Circuit Diagram. AS1164.2.

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