SOLARTRON

Instruction Manual
for
Analogue Computer
SCD 10

THE SOLARTRON ELECTRONIC GROUP LTD
FARNBOROUGH · HANTS · ENGLAND

SOLARTRON

SCD 10 ANALOGUE COMPUTER

MAINTENANCE MANUAL

FOREWORD

The SCD 10 analogue computer is a small general purpose machine suitable as a design tool or as an educational aid. It comprises ten drift-corrected D.C. amplifiers, each of which may be used for summing, sign reversing, or integrating; twenty-four potentiometers, a patching panel, computer control facilities and built-in power supplies. An additional ten amplifiers can be incorporated, these can be used as 2 input summers. Simple non-linear elements are included, and servo-multipliers are readily incorporated to expand the scope of the computer. Two SCD 10 machines may be used in conjunction with one another, with one control unit operating both machines.

The following problems are typical of those which may be solved on a single SCD 10.

(a) Single differential equations of up to fifth order.

(b) Two simultaneous differential equations, up to third order.

(c) Multiple loop servo-systems.

(d) Aerodynamics simulation for guided weapon control systems.

(e) Dynamical mechanical systems, of for instance, the mass, spring, viscous damping type.

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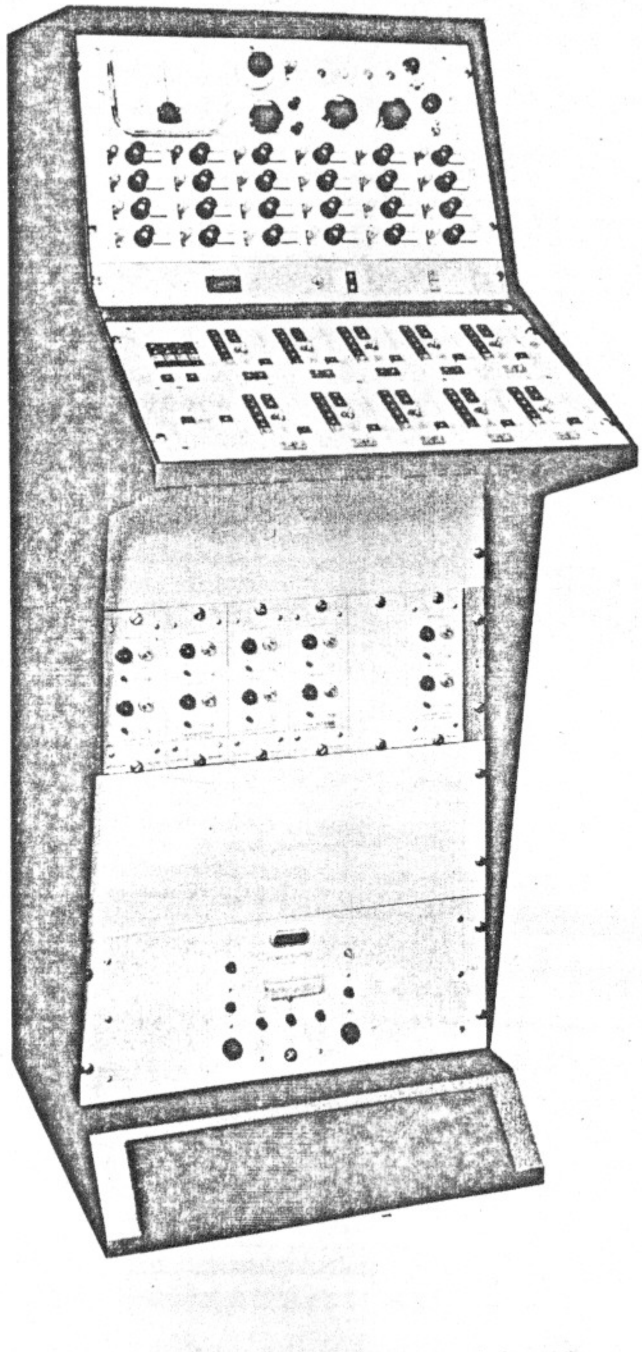


Frontispiece Basic SCD 10

TECHNICAL DESCRIPTION

General

1. The SCD 10 Analogue Computer is housed in a console type cabinet. In its simplest form it consists of the following sub-assemblies.

(1) Control Panel

(2) Patch Panel

(3) Five drift-corrected Operational Amplifier Units Type AA. 1054

(4) Computer Power Supply Type AS. 1104

(5) Air Blower.

Provision is made to extend the scope of the computer by the inclusion of an extra five dual operational amplifiers, (summing only) and also the addition of non-linear units such as servo multipliers, servo resolvers, diode function generators, electronic multipliers (time division).

Details of these additional units and their respective conversion kits are given in the appendices at the rear of the manual.

2. The five twin computer amplifiers are carried in one amplifier Mounting Unit Type TX. 1269 (Rack A).

3. Since the SCD10 handbook includes copies of the instruction manual for the modules associated with the basic SCD10 computer viz:

(a) Operational Amplifier Unit AA. 1054

(b) Computer Power Supply Type AS. 1104

(c) Amplifier Mounting Unit Type TX. 1269

these component equipments will not be further considered here.

CONTROL PANEL

Function

4. The panel provides a central control point for the relays, switching the input resistors and feedback elements associated with the operational amplifiers. It contains certain electronic circuitry for the control and operation of the computer, and provides power reference voltage and amplifier output monitoring facilities. The 24 co-efficient setting potentiometers are also mounted on the control panel.

Panel Fittings

5. The control panel carries the controls, indicator lamp and meter as listed.

RV3	REFERENCE potentiometer
RV6-RV9	Earth-free potentiometers numbered 1-4
RV10-RV29	Earthed potentiometers
SW1	Overload HOLD switch
SW2	Amplifier OUTPUT SELECTOR, eleven position
SW3	Function selector, eight position: POT SET; PROBLEM CHECK; COMPUTE; HOLD; REP; 1, 2 and 5 sec.
SW4	Meter switch, 8 position, +300V, -300V, -200V, +100V, -100V, +30V, V, NULL
SW5	Internal or external ±100V key switch for use with RV3
SW7	MAINS switch
SW21	Meter switch for 10V range
SW22	Meter switch for 1V range
SW25-SW28	Key switches for RV6-RV9
SW29-SW48	Key switches for RV10-RV29
M1	Meter centre-zero f. s. d. 100μA-0-100μA
LP1	OVERLOAD indicator lamp (red)
LP1	POT SET indicator lamp (blue)
LP3	PROBLEM CHECK indicator lamp -(orange)
LP4	COMPUTE indicator lamp (green)
LP5	HOLD indicator lamp (red)
FS1	Mains fuse
JK1	Jack socket for monitoring computer amplifier output voltages by means of a digital voltmeter
SK2-SK6	Recording outlets (refer paragraph 52)

Additional Facilities
(Rear Panel)

6. SW10 A three-position selector switch used only when a diode function generator is fitted into the computer (refer Appendix B).

Central Overload Indicator
(Refer Fig. 1)

7. The overload circuit gives visual warning at the central control panel when any one or more of the operational amplifiers runs into a signal overload condition, and also when the +300V and -200V HT lines are overloaded. The circuit employed is of the monostable type triggered by positive pulses from a high gain two stage amplifier consisting of two pentode valves connected in cascade to give high sensitivity.

8. The overload outputs on the individual amplifiers of rack A are commoned and connected through pin 15 of SK14 to the input of the control panel central overload indicator. When additional operational amplifiers are fitted (rack B) the overload outputs from these individual amplifiers on rack B are commoned and fed to the overload circuit through pin 16 of SK14. In the event of an overload on the +300 volt and -200 volt lines from the power supply AS.1104, a pulsed overload signal of 18 volts approximately is fed from the AS.1104 to trigger the central overload circuit. The overload indicator lamp on the power supply AS.1104 will also begin flashing, thereby indicating that the overload exists on the main HT lines. This overload signal from socket SK6 on the HT line of the power supply is fed through to pins 7 and 8 on SK14 and then into the central overload indicator circuit. When servos are fitted, the overload signal from these are also fed through to the central overload circuit through pins 7 and 8 on SK14.

On applying power to the overload circuit the OVERLOAD indicator lamp will light, but this will be extinguished when the HT supply becomes available and valve V2B passes anode current to pull-in relay RLD/2. All signal inputs applied to the overload circuits are fed through a 1MΩ resistor and thence to the grid of the pentode V12. Output signals from V12 are capacitively coupled onto the input grid of pentode V1. Signal input to this grid is limited to approximately 100mV peak-to-peak by the silicon diodes MR1 and MR2. The output from the anode V1 is coupled to the grid of V2A via the clamping circuit C2, MR3, MR4 and R8. The voltage drop across resistor R16 establishes the reference potential of the clamp which is approximately 10 volts negative with respect to the potential of V2B grid. Thus any positive-going pulse having an amplitude greater than 10 volts will trigger the uni-vibrator V2. The filter circuit comprising R7 and C18 serve to reject noise voltages generated by power switching and relay operation which might otherwise trigger the monostable and signal a spurious overload. In the stable condition V2B will be conducted and V2A will be cut off by virtue of the bias potential developed across the common cathode resistor R10 by V2A anode current, which also holds in relay RLD/2. On the incidence of a positive pulse of sufficient amplitude (greater than 10 volts) at the grid of V2A, that valve section will pass anode current and regeneratively cut off V2B. Relay RLD/2 will thereon drop out and contact, RLD/1 will close to energise indicator lamp LP1 and thus signal an overload condition, refer Fig. 10. The association of V2B anode

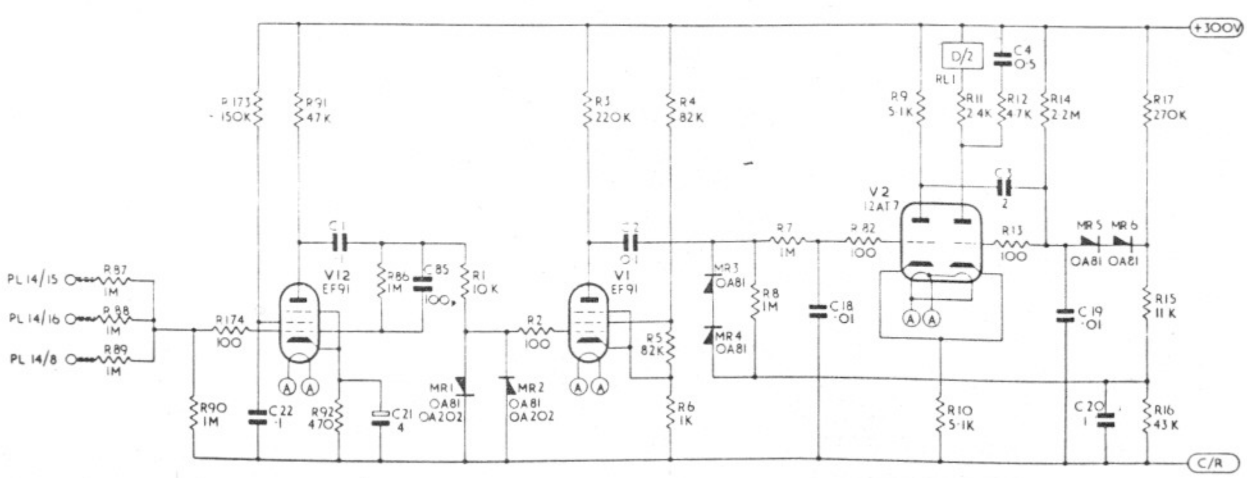


Fig. 1 Circuit Diagram - Central Overload Indicator

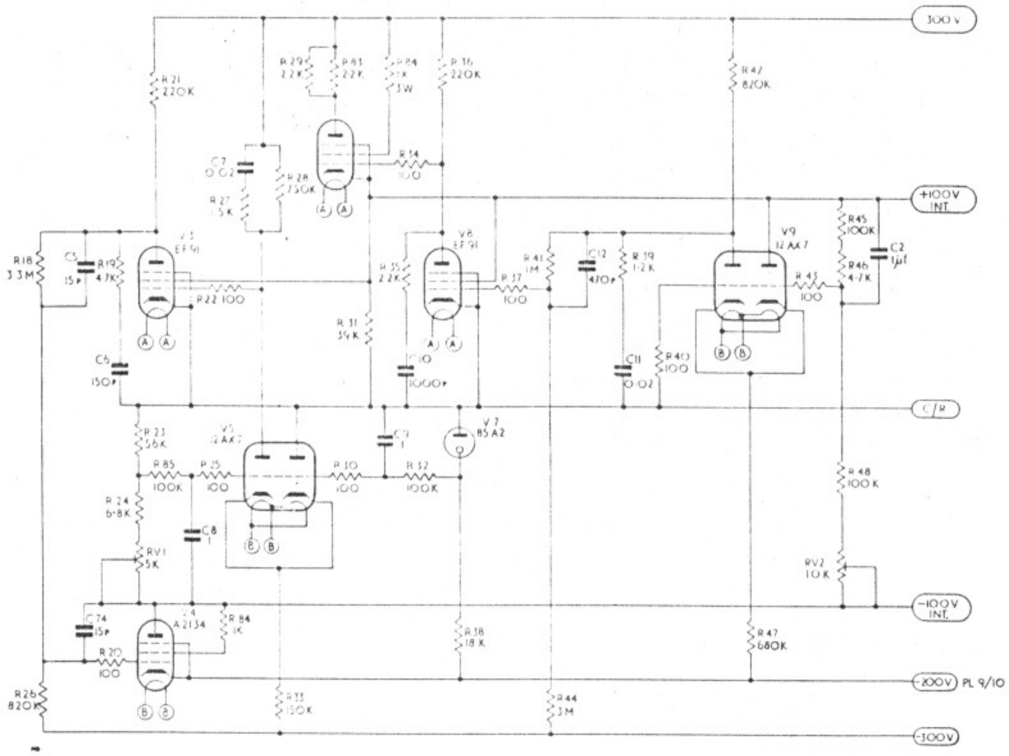


Fig. 2 Circuit Diagram - ±100 V Reference Power Supply

current removes the cathode bias potential holding V2A at cut off, and this valve again conducts to restore the monostable to its stable condition. Capacitor C3 will now discharge through resistor R14 since it cannot discharge through MR5 and MR6. The negative potential on the grid of V2B will decrease until that valve again passes anode current to pull-in relay RLD/2. The time constant of the discharge path is approximately 1 sec. so that providing the overload is maintained, it will be signalled by a series of flashes from LP1.

-100 Volts Reference Power Supply (Refer Fig. 2)

9. The -100 volts reference supply is derived from a degenerative amplifier type of stabiliser which itself is powered from stabilised voltages provided by the power supply Type AS. 1104.

10. The circuit employs four valves; a gas discharged voltage reference tube V7, a double triode differential amplifier V5 driving a pentode amplifier V3, and a pentode series control valve V4. The power for the circuit is derived from the stabilised -200 volts and -300 volts source, with the exception of V5B anode which is returned to the common rail. The grid potential of V5B is held at a fixed negative value with respect to the common rail by the voltage reference tube V7 which has a burning voltage of 85 volts. Resistor R32 and capacitor C9 form a filter to remove ripple voltage from the reference potential, in the interest of hum reduction. Resistors R23 and R24 and RV1 form a sampling chain connected across the common rail and -100 volts rails to provide the signal input to the differential amplifier.

Assuming that the potential of the -100 volts output supply has moved in a negative direction, then the grid potential of V5A will go positive with respect to the cathode.

The increased anode current of V5A will develop a greater bias voltage across resistor R33, and since the grid potential of V5B is held constant by V7, V5B anode current will decrease and the control grid of V3 will move in a positive direction. A resultant negative-going signal appearing at the anode of V3 is applied to the grid of the series control valve V4 to increase the effective DC resistance of that valve, and thus off-set the rise in output voltage which initiates the regulation cycle. Variable resistor RV1 enables the potential of the stabilised reference supply to be accurately set at -100 volts.

+100 Volts Reference Power Supply (Refer Fig. 2)

11. The +100 volts reference supply is derived from a degenerative amplifier type of stabiliser, which itself is powered from stabilised voltages provided by the power supply Type AS. 1104.

12. The circuit employs three valves, a double-triode differential amplifier V9 driving

a pentode amplifier V8, and a pentode series control valve V6. The reference voltage to the differential amplifier is provided by the -100 volts supply. The sampling chain providing the signal input to the differential amplifier is made-up of resistors R45, R46 and RV2. The grid of V9B is returned to the electrical centre of this voltage dividing network, so that the grid potential is essentially that of the common rail, as also is the grid potential of V9A. Assuming that the voltage of the +100 volts supply moves in a negative direction, e.g. to 90 volts, V9B grid potential will move negatively, and the decreased anode current will reduce the bias voltage developed across R47. The anode current passed by V2A will thereon increase to produce a negative-going signal at the anode. This in turn drives the grid potential of V8 in a negative direction, and the resultant positive-going signal appearing at the anode of V8 is applied to the grid of V6 to decrease the effective d.c. resistance of the series control valve.

Variable resistor RV2 enables the potential of the reference supply to be accurately set at +100 volts.

Repetitive Timer
(Refer Fig. 3)

13. The repetitive timer consists of an electronic timing device triggering a monostable circuit, which in its stable condition switches the instrument to COMPUTE for a period of one, two or five seconds, as determined by the timer, and in its unstable condition switches the computer for a one-second reset period.
The timing circuit consists of a Miller run-down valve, with the control grid returned to switched positive potentials of approximately 38, 10 and 200 volts to give timing periods of five, two or one second respectively. When the function selector is not set to any one of the three REP. positions, the run-down valve V10 is held at cut-off by the application of negative potentials to the control and suppressor grids. These potentials are derived from a voltage divider (R58, R59, R63) connected across the -300 volts and common rails. The monostable V11 will be in its stable conditions, with V11A conductive and V11B cut-off. The anode relay RLE/2 will therefore be de-energised.

14. On setting the function selector to any one of the REP. positions, the appropriate positive potential is applied to V10 control grid via switch-bank SW3E, and at the same time the suppressor grid is returned to the common rail via relay contact RLE.1 and switch-bank SW3D. Valve V10 will now pass anode current and the linear run-down of anode potential will be initiated and continue as capacitor C13 discharges to raise V10 control grid potential.

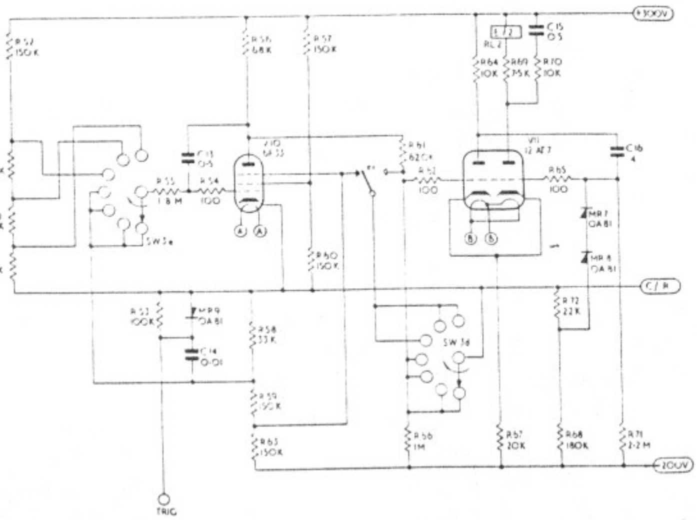


Fig. 3 Circuit Diagram - Repetitive Timer

The falling potential at the anode of V10 is applied to the grid of V11A so that at the end of the run-down (COMPUTE) period V11A is cut-off, and V11B regeneratively cut-on to energise relay RLE/2. Thereon, contact RLE/2 will change over to:-

(1) Energise via switch-bank SW3B indicator lamp LP3 and relay RLA/2, which switches all operational amplifiers from the COMPUTE to RESET conditions. Refer Fig. 1.

15. Also following the operation of relay RLE/2, contact RLE/1 will change over to:-

(1) Cut-off V10 by disconnecting the suppressor grid from the common rail, and thus reinstating the negative bias potential applied so that electrode from the voltage divider R58, R59 and R63. Capacitor C13 will now charge-up to reset the stage for the next COMPUTE timing period.

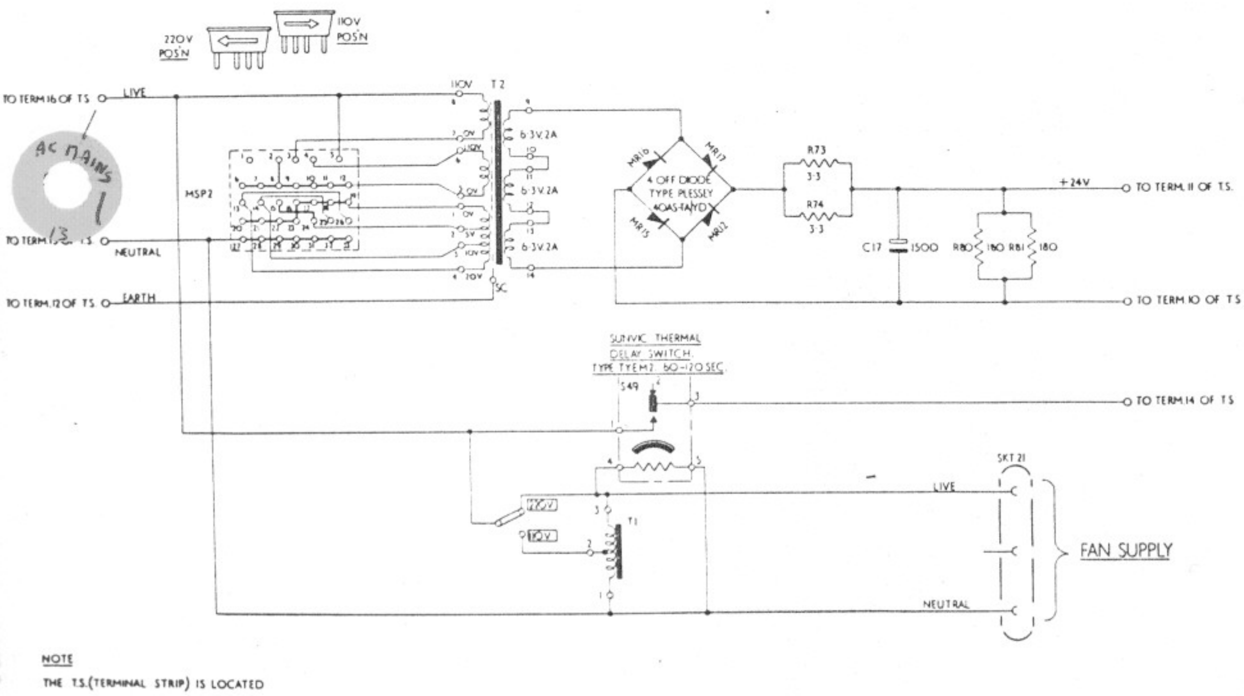
16. The charge on capacitor C16 will leak away through resistor R71 until V11B grid potential becomes sufficiently negative to cut-off V11B and to cut-on V11A. Relay RLE/2 will then drop out to terminate the one second RESET period, and contacts RLE/2 and RLE/1 will change over to switch the instrument to a further COMPUTE period and trigger the run-down valve V10. Capacitor C14 and germanium diode MR9 provide a positive pulse at the commencement of each COMPUTE period for the purpose of synchronising external equipment. This trigger pulse is available at co-axial socket SK6 at the rear of the cabinet.

Meter Circuit
(Refer Fig. 4)

17. The centre-zero meter is wired to a double-pole 8-position selector SW4 so that it can be switched to:-

(1) Monitor supply voltages

(2) Monitor amplifier outputs



NOTE
THE T.S.(TERMINAL STRIP) IS LOCATED ON THE INSIDE OF CONSOLE R.H. SIDE VIEWED FROM THE REAR.

Fig. 4 Circuit Diagram - 24 V DC Relay Supply

(3) Monitor external voltages

(4) Facilitate setting of co-efficient potentiometers.

18. Resistors R75, R76 and R175 are multipliers giving full-scale deflections for inputs of ±300 volts and ±100 volts and +30 volts respectively. When monitoring amplifier output voltages, the appropriate amplifier is switched into the meter circuit by the OUTPUT SELECTOR SW2, the METER switch being set to position V. Since, in this condition, the multiplier resistor is R76, full-scale deflection will be obtained with an input of ±100 volts.

Measurement of External DC Voltages

19. The meter can also be used for the direct measurement of external d.c. voltages not exceeding ±100 volts. When used in this application the METER selector SW4 is set to the "V" position, and the amplifier OUTPUT SELECTOR to OFF. The external voltage is applied across the violet coloured "V" socket (line) and any one of the signal ground "SG" black coloured sockets on the 36-way General Patch Panel. The multiplier resistor is again R76, value 1 megohm, and the input is therefore limited to ±100 volts. External measurement of amplifier voltages may also be effected by plugging in a digital voltmeter into the jack socket JK1 located on the control panel. When an external digital voltmeter is used the panel meter becomes ineffective in the NULL and V positions.

Setting of Coefficient Potentiometers

20. The accurate setting of coefficient potentiometers is facilitated by using the meter as a null-deflection indicator. For this purpose, the METER selector SW4 is set to NULL, and the amplifier OUTPUT SELECTOR SW2 to OFF. The appropriate voltage is then set up on the reference potentiometer RV3, and backed-off by the armature voltage of the coefficient potentiometer until the meter shows no deflection. The initial adjustment is made with multiplier resistor R77, value one megohm, in circuit, to give a full-scale deflection of ±100 volts. Push-buttons SW21 and SW22 introduce multiplier resistors R78 and R79 to increase the sensitivity of the meter to 10 volts and 1 volt full-scale deflections respectively, thus ensuring accurate final setting of the coefficient potentiometer. Switch SW5 enables the high end of the reference potentiometers to be connected to the plus or minus internal or external 100 volts reference supply as required. Relay contacts RLF/1 and RLF/2 automatically select the internal or external ±100 volts reference supply in accordance with the setting of the INT/EXT. selector SW6 carried on the rear panel of the cabinet. The armature of the coefficient potentiometer is connected to the meter input by depression of the appropriate key-switch, a second bank of the switch at the same time connecting the +100 volts reference supply to the high end of the potentiometer.

Measurement of External DC Voltages by Null Method

21. The meter circuit can also be employed in conjunction with the reference potentiometer RV3 to accurately measure d.c. voltages within the range 0 to ±100 volts by the null-deflection method. When used in this application, the METER selector SW4 is set to NULL and the amplifier OUTPUT SELECTOR SW2 set to OFF. The voltage to be measured is applied across the violet coloured "V" socket (live) and any one of the signal ground "SG" black coloured sockets on the 36-way General Patch Panel. The reference supply of appropriate polarity is switched to the high end of the reference potentiometer which is then adjusted for null-deflection on the meter. The value of the input voltage is now read off the potentiometer dial. The push buttons SW21 and SW22 are again used to increase the sensitivity of the meter so that a precise null-indication is readily obtainable.

Computer Switching

22. The forward path resistors and the resistive and capacitive feedback elements associated with each amplifier form part of the 25-way Amplifier Patch Panel associated with that amplifier. These feedback elements are switched for integration or summing by three relays (RLA/1, RLB/2, RLC/2) and the SUM/INT. selector, which components are repeated on all ten 25-way Amplifier Patch Panels. The Control Panel carries a function selector which is virtually a master control simultaneously switching the forward path resistors and feedback elements associated with all ten patch panels to the required configuration. The function selector SW3 is a seven-way, five-bank switch with functional settings designated POT. SET, PROBLEM CHECK, COMPUTE and HOLD. Three repetitive positions are provided whereby the amplifiers can be automatically switched for a one, two or five seconds COMPUTE period, each followed by a one second RESET period. The switching sequence for each function is described in paragraphs 23-27.

The Silicon Diodes MR18-23, connected between the switching contacts and the 24 volts supply, prevent reverse current appearing across the contacts during switching.

Potentiometer Set Condition

23. The function selector is turned to POT. SET, and relay RLC/1 and indicator lamp LP2 (POT. SET) will be energised via contact RLB/1, SW3A and SW3B. Relay RLA/2 will be energised via contact RLB/1 and SW3B. Thereon:

(1) Contact RLA/1 will change-over to apply the 24 volts d.c. supply to the PROBLEM CHECK (RESET) line.

(2) Contact RLC/1 will change-over to apply the 24 volts d.c. supply to the HOLD OPERATE line.

Problem Check

24. Indicator lamp LP3 (PROBLEM CHECK) will be energised via contact RLB/1, SW3A and SW3B. Relay RLA/2 will be energised via contact RLB/1 and SW3B.

(1) Contact RLA/1 will change-over to apply the 24 volts d.c. supply to the PROBLEM CHECK (RESET) line.

Compute

25. Indicator lamp LP4 (COMPUTE) will be energised via contacts RLB/1, RLA/2 and SW3C. No relays will be energised.

Hold

26. Relay RLB/2 and indicator lamp LP5 (HOLD) will be energised via SW3C.

(1) Contact RLB/1 will change-over to apply the 24 volts d.c. supply to the HOLD NORMAL line.

Repetitive Positions

27. During the one, two or five seconds timed COMPUTE period, CONTACT RLE/2 will be open; no relays or lines will be energised. The COMPUTE indicator lamp LP4 will be lit via contacts RLB/1, RLA/2 and SW3C. At the end of the COMPUTE period, contact RLE/2 will close to energise the PROBLEM CHECK indicator lamp LP3 via SW3B and SW3A, and also relay RLA/2 via SW3B and contact RLB/1.

(1) Contact RLA/1 will change over to apply the 24 volts d.c. supply to the PROBLEM CHECK (RESET) line.

On the termination of the one second RESET period, contact RLE/2 will open to switch the instrument to a further one, two or five second COMPUTE period.

Overload Hold Facility

28. In the event of an amplifier overload being signalled by indicator lamp LP1 (overload circuit) the amplifier can be held in the overload condition by moving toggle-switch SW1 from the OFF position. The HOLD relay RLB/2 and indicator lamp LP5 will then be energised via contact RLD/2, SW1 and SW3C when set to COMPUTE or any of the three repetitive positions. Contact RLB/2 will now close to hold-in relay RLB/2, and contact RLB/1 will close to energise the HOLD NORMAL line to maintain the amplifier in the overload condition. The offending amplifier can now be identified by inspection of the neon lamp overload indicators carried on the panels of the individual amplifiers. The EXTERNAL HOLD connections are for use when two SCD 10 computers are coupled and operated as a single installation from one of the Control Panels.

24 Volts DC Relay Supply
(Refer Fig. 4)

29. The mains power for the 24 volts DC Relay supply system is taken from the switched side of the mains switch (SW7) and through a mains tapping panel onto a transformer (T2). This transformer has series connected primary windings which may be adjusted for inputs of 110V or 220V ±5, 10 or 20V by the mains selector panel MSP2. The secondary windings consist of 3 windings connected in series to give approximately 20 volts output. This output is fed to a bridge-connected rectifier network consisting of silicon diodes MR12, MR13, MR16 and MR17 to produce a d.c. output at 24 volts.

Resistors R73, R75 and capacitor C17 form a ripple filter, whilst bleed resistors R80, R81 are included to improve the regulation of the supply.

30. The INT./EXT. switch SW6, mounted on the rear panel of the cabinet, is for use when two SCD 10 computers are coupled for operation as a single installation from one of the Control Panels. In these circumstances, a common 24 volts supply and ±100 volts reference supply should be used. The INT./EXT. switch disconnects the computer function switching relays from the internal 24 volts d.c. supply and connects them instead to the external 24 volts supply provided by the other SCD 10 computer. At the same time, relay RLF/2 is energised and contacts RLF/1 and RLF/2 change-over to connect the external ±100 volts reference supply to the reference and coefficient potentiometer circuits.

31. The diode function generator selector switch (SW10) mounted on the rear panel, is for use only when diode function generators are fitted. The switch has three positions designated 0, 1 and 2, and should be set at the ZERO position if diode function generators are not required for operation in the computer. Reference to appendix B in the manual will give the functions of the selector switch in the alternative positions (1 & 2) and the relevant computer function.

Potentiometer Panel

32. The panel carries four earth-free and twenty earthed, wire-wound, ten-turn, helical potentiometers each having a value of 30,000 ohms.

Free Potentiometers

33. The armatures, high and low extremities of the four earth-free potentiometers are internally wired to the 12 orange coloured sockets on the General Patch Panel. The sockets connected to the armature, high and low extremities of the potentiometers are identified by the designations A. H. and L respectively, whilst the potentiometers are designated by the numerals 1-4. Associated with each free potentiometer is a single-pole change-over switch which, when depressed connects the armature of the appropriate potentiometer to the voltmeter input circuit.

Earthed Potentiometers

34. One extremity of all twenty of these potentiometers is permanently wired to earth. The high extremities and armatures are internally connected to the ten 25-way Amplifier Patch Panels; two potentiometers being connected to each panel. The sockets are coloured orange, and are identified by the designations H1, A1, H2 and A2. Associated with each of the earthed potentiometers, is a double-pole change-over switch which, when depressed:

(1) Connects the high end of the selected potentiometer to the +100 volts reference potential, at the same time disconnecting it from the patch panel socket.

(2) Connects the armature of the

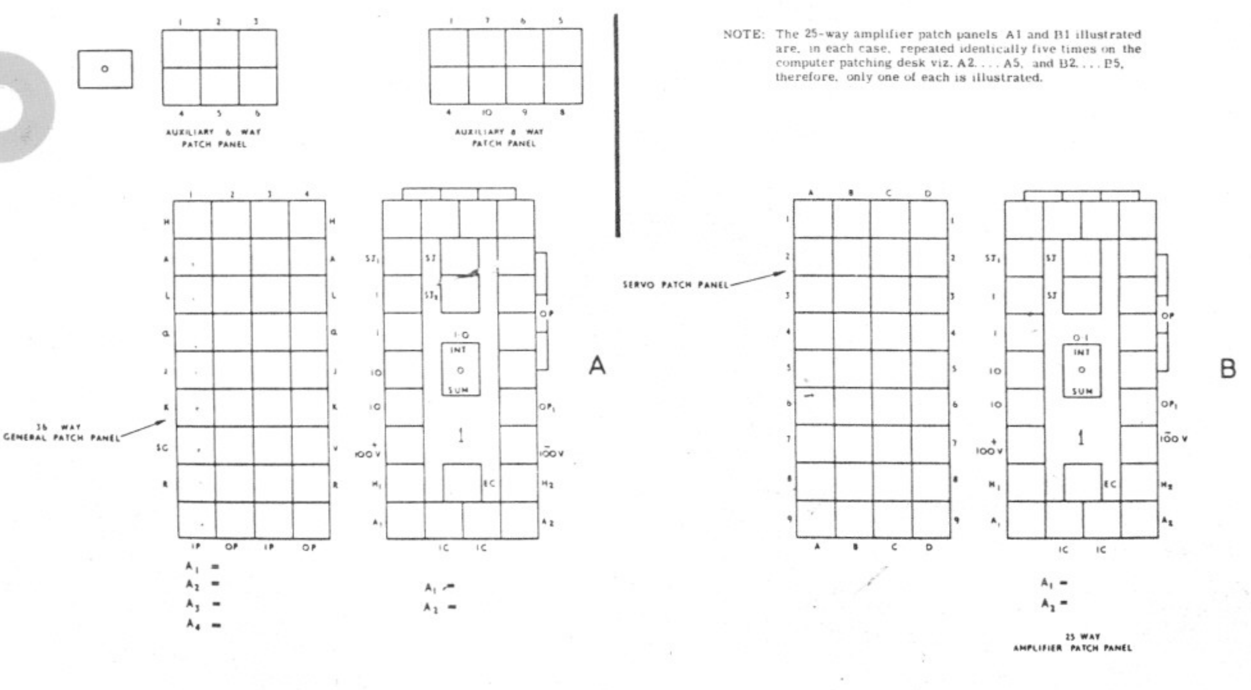


Fig. 5 Amplifier Patch Panel Functions

selected potentiometer to the voltmeter input circuit.

35. The voltmeter input line is routed serially through all the 24 key switches as a potentiometer protective measure. The order of connection is given in Fig. 9. It follows therefore, that if any key switch is inadvertently left in the "down" position, it will not be possible to meter the armature voltage of any of the succeeding potentiometers.

PATCH PANEL
(Refer. Fig. 5)

General

6. The Patch Panel consists of:

(1) Ten (one per amplifier) similar 25-way Amplifier Patch Panels, each wired with forward path resistors and feedback elements, and fitted with a SUM/INTegrate selector and three relays for switching these elements.

(2) One 36-way General Patch Panel wired to the earth-free potentiometers, diode pairs, signal ground, voltmeter input line, recording outputs, and various multiway terminations for external control functions.

(3) One 36-way patch panel, used only on computers fitted with servo multiplier units.

(4) One six-way and one eight-way auxiliary patching panel located immediately above the main body of the Patch Panel but in the same plane as the Control Panel.

The functions of all sockets having specific uses are designated by engraved legends, and additionally, some sockets are identified by a colour coding system thus:-

Summing junctions	- green
Amplifier inputs	- blue
Amplifier outputs	- yellow
Potentiometer connections	- orange
Signal Earth	- black .

AMPLIFIER PATCH PANEL

(Refer Fig. 5)

General

37. Each Amplifier Patch Panel carries 25 sockets and one SUM/INT. selector. The functions and colour coding of these sockets are listed in Table 1.

The Patch Panel Circuit Diagram shows only the Amplifier Patch Panel A1, which is associated with the similarly designated (A1) amplifier. It should be borne in mind that there are in fact nine further such patch panels, which, for reasons of space limitation and simplicity are not shown on the circuit diagram. These nine panels are physically identical with panel A1, and differ only in respect of amplifier and coefficient potentiometer connections.

Input Circuit

38. Four input resistors are provided, two (Ra, Rb) having a value of 1 megohm, and two (Rc, Rd) having a value of 100,000 ohms. These forward path components, in conjunction with the feedback resistor Rh (value one megohm) give gains of unity and ten respectively. Any number of these input resistors can be connected in parallel to obtain any integral gain from 1 to 22. Equally, up to four inputs may be summed, the gain to each being dependent on the value of the appropriate input resistor. To compensate for the inherent capacitance between the summing junction and the amplifier output, capacitors Ca - C4 are wired in parallel with the input resistors. The remote ends of all four resistors are commoned and relay switched to the summing junction or to signal earth according to the computing function which the amplifier is required to perform.

Feedback Elements

39. Two feedback elements are provided, a capacitor Ce for integrating, and a resistor Rh for summing. Capacitor Cf is provided to maintain overall stability of the amplifier. On 'A' amplifiers capacitor C3 has a value of one microfarad, whilst on 'B' amplifiers it has a value of 0.1 microfarad. The value of resistor Rh is one megohm on both 'A' and 'B' amplifiers. These feedback elements are selected by the contacts of relay RLC/2, which in turn is controlled by the SUM/INT. switch SWA.

40. Bearing in mind that when the installation is switched to COMPUTE at the Control Panel, lines 1, 2 and 3 are not energised, on setting switch SWA to SUM, relay RLC/2 will operate. Contacts RLC/1 and RLC/2 will thereon change-

TABLE 1

AMPLIFIER PATCH PANEL SOCKET FUNCTIONS

Socket Designation	Colour	Function
SJ	Green	Amplifier input
SJ1	Green	Junction Internal summing resistors
SJ2	Green	Amplifier input end of internal feedback element
1	Blue	Unity gain input
1	Blue	Unity gain input
10	Blue	Ten gain input
10	Blue	Ten gain input
OP	Yellow) Yellow) Yellow) Yellow)	Four internally linked amplifier output terminals
OP1	Yellow	Output end of internal feedback element
+100V	Red	+100V reference voltage
-100V	Purple	-100V reference voltage
H1	Orange	High end potentiometer 1
A1	Orange	Armature potentiometer 1
H2	Orange	High end potentiometer 2
A2	Orange	Armature potentiometer 2
IC IC	Red) Red)	Input for initial condition voltage (internally linked)
EC	White	External connector
	White) White) White) White)	Four internally connected spare multiple links

over to connect feedback resistor Rh between sockets OP1 and SJ2. Insertion of shorting links between socket SJ - SJ2, and OP - OP1, will effectively connect the feedback resistor Rh across the summing junction and output of the associated amplifier. The feedback capacitor Ce will be earthed via contact RLC/1 and resistor Rg.

41. When switch SWA is set to INT., relay RLC/2 will drop-out, and feedback capacitor Ce will be connected between sockets OP1 and SJ2. Insertion of shorting links between sockets SJ - SJ2, and OP - OP1 will connect the feedback capacitor across the summing junction and the output of the associated amplifier. The feedback resistor Rh will now be earthed via contact RLC/2. The integrating circuit now obtained is in all but one respect identical to that shown in Fig. 12 Chapter 2 for the summing circuit, the exception being that the feedback resistor is now replaced by the feedback capacitor.

Initial Condition Setting Resistors

42. Two resistors Re, Rf are provided to permit setting-up the initial conditions prior to an integration. Electrically this entails charging up the feedback capacitor Ce to a precise voltage as required by the problem to be solved. When setting up the initial condition the installation is switched at the Control Panel to POT. SET., and patch panel relay control lines 1 and 3 will be energised. Therefore with the patch panel switch SWA set to INT., the status of the relays will be:-

RLA/1 de-energised
RLB/2 energised
RLC/2 de-energised.

In these circumstances:-

(1) The input resistors Ra - Rd will be earthed via contact RLB/1.

(2) The junction of resistors Re and Rf will be connected to the summing junction via contacts RLB/2 and RLA/1.

(3) The feedback capacitor Ce will be connected across OP1 and SJ2 via contact RLC/1.

On patching the ±100 volts reference supply according to the polarity of charge required to the high end (H1) of the potentiometer and patching the armature (A1) to a 1C socket, the circuit is obtained. In practice the initial condition voltage is firstly set up on the Control Panel reference potentiometer RV3, and backed off by the amplifier output voltage for zero deflection of the built-in voltmeter.

Problem Check Switching

43. With the Control Panel function selector set to PROBLEM CHECK, patch panel relay control line 3 will be energised. On amplifiers switched by SWA to INT., relay RLB/2 will be energised, and relays RLA/1 and RLC/2 de-energised. This is the POT. SET conditions as described in paragraph 42. The initial conditions can now be checked as direct voltmeter readings by scanning the outputs of the integrating amplifiers using the amplifier OUTPUT SELECTOR SW2. If desired, the coefficient potentiometer setting-up procedure can be repeated as a further check.

44. On amplifiers switched by SWA to SUM, only relay RLC/2 will be energised, bringing these amplifiers to the COMPUTE condition. The summing amplifier output voltages can now be checked on the built-in meter using the amplifier OUTPUT SELECTOR SW2.

Hold Switching

45. With the Control Panel function selector set to HOLD, patch panel relay control line 2 will be energised. Relay RLA/1 will be operated via switch SWA to the INT. position. In this condition the summing junctions of the input resistors will be earthed via contacts RLB/1 and RLA/1, thus leaving the feedback capacitor Ce charged to the voltage across it at the time computing was arrested. The solution at this instant can now be recorded by a suitable device.
Since as a result of grid and leakage currents at the amplifier input, the arrested voltage on the capacitor cannot persist indefinitely, the accuracy of any solution obtained will be reduced as the time lag between the instants of arrest and solution is increased.

Amplifier Overload Hold

46. Operation of the OVERLOAD HOLD switch SW1 on the Control Panel will also apply the 24 volts d.c. potential to patch panel relay control line 2. -Relay RLA/1 will then operate to earth the summing junctions of all integrating amplifers and hold them, and any affected summing amplifiers, in the overload condition. The neon overload indicator lamps on the individual amplifiers can now be inspected and the offending unit or units located.

External Connection

47. The white EC socket is connected to the 24-way socket SK13 carried on the rear panel of the SCD10, to permit the connection of ancil-

SK/TP. 1575

TJ 725

A	B	C	D	
AH	AA	AL	NOT USED	1
CH	CA	CL	NC	2
DL	BA	DA	DH	3
EL	EA	BL	EH	4
I/P	BH	BH	I/P	5
EL	EA	BL	EH	6
DL	BA	DA	DH	7
CH	CA	CL	NC	8
AH	AA	AL	NOT USED	9

TJ 1231.2
POT ASSY
123121

A	B	C	D	
DH	DS	DL	DC	1
CH	CS	CL	EC	2
FL	BS	FS	FH	3
EL	ES	BL	EH	4
I/P	BH	BH	I/P	5
EL	ES	BL	EH	6
FL	BS	FS	FH	7
CH	CS	CL	EC	8
DH	DS	DL	DC	9

NOT RECOMMENDED FOR USE IN SCD 10

TJ 1231.2
POT ASSY
123123

A	B	C	D	
DH	DA	DL	N.C	1
CH	CA	CL	N.C	2
FL	BA	FA	FH	3
EL	EA	BL	EH	4
I/P	BH	BH	I/P	5
EL	EA	BL	EH	6
FL	BA	FA	FH	7
CH	CA	CL	N.C	8
DH	DA	DL	N.C	9

TJ 1231.2
POT ASSY
123125

A	B	C	D	
DH	DS	DL	DC	1
CH	CA	CL	EC	2
N.C	BA	N.C.	N.C	3
EL	ES	BL	EH	4
I/P	BH	BH	I/P	5
EL	ES	BL	EH	6
N.C.	BA	N.C.	N.C.	7
CH	CA	CL	EC	8
DH	DA	DL	N.C	9

THE FIRST LETTER REFERS TO THE POTENTIOMETER AND THE SECOND TO HIGH, ARM, LOW, SINE & COSINE.
N.C.:- NO CONNECTION.

Fig. 6 Servo Multiplier and Resolver Connections lary apparatus to the amplifier associated with that patch panel, the four internally connected white sockets at the top of the patch panel are for use as a spare multiple link.

GENERAL PATCH PANEL

(Refer. Fig. 5)

General

48. The General Patch Panel carries 36 sockets, the functions and colour coding of which are listed in Table 2.

Earth Free Potentiometer Sockets

49. The armature (A), high (H) and low (L) ends of the four earth-free potentiometers are wired to the 12 orange coloured patch sockets.

Diode Sockets

50. Four pairs of diodes, each pair having one anode to cathode connection, are wired to the A (anode), J (junction) and K (cathode) rows of sockets. These diodes are for use in conjunction with the four earth-free potentiometers for the generation of discontinuous functions.

Voltmeter Line

51. The violet coloured "V" socket enables external d.c. voltages not exceeding ±100 volts to be measured on the internal voltmeter. Refer paragraph 21.

Outlets to Recording Device

52. Four white sockets designated R1, R2, R3 and R4 are wired to four correspondingly designated coaxial sockets (SK2 - SK5) carried on the rear panel of the cabinet. The output or input of any operational amplifier can be applied to a recording device connected at the appropriate coaxial socket by means of a patch cord between the relevent "R" patch socket and the appropriate socket on the Amplifier Patch Panel. Conversely, the coaxial sockets SK2 - SK5 can be employed to connect test equipment to any operational amplifier via the General and Amplifier Patch Panels.

Function Generator

53. The lower four sockets on the General Patch Panel are used for the input and outputs for the two function generators when incorporated. These four sockets are also connected to socket SK13 mounted on the rear panel of the cabinet and can be used for external connections when the function generators are either not in use or not incorporated.

Servo Multiplier Patch Panel
(Refer Fig.6)

54. The Servo Multiplier Patch Panel will only be wired if the SCD10 has been fitted with a Servo Multiplier Conversion Unit Type TX967. The connection to the servos are given in Fig.9. Note that potentiometer assembly type 123121 in the TJ1231.2 servo is not recommended for use in the SCD10, because there are insufficient patch connections for all of the terminals of the sine/cosine potentiometers.

Auxiliary Patch Panel

55. The Auxiliary Patch Panel consists of one group of six and one group of eight patch sockets carried on a narrow panel immediately above the main body of the Patch Panel, but in the same plane as the Control Panel. The group of six is wired to the selector and poles of a two-way change-over switch SW8. The group of eight is wired to the coil and contacts of the two-pole change-over relay RL7. These socket groups together with the associated switch and relay permit single or double-pole, on-off or change-over operations to be patched for manual or remote operation.

There are additional sockets on this Patch Panel when modification kits Type TX 1125 and TX 1127 are incorporated.

TABLE 2

GENERAL PATCH PANEL SOCKET FUNCTIONS

Socket Designation	Colour	Function
H1	Orange	Free potentiometer 1, high
A1	Orange	Free potentiometer 1, armature

Socket Designation	Colour	Function
L1	Orange	Free potentiometer 1, low
H2	Orange	Free potentiometer 2, high
A2	Orange	Free potentiometer 2, armature
L2	Orange	Free potentiometer 2. low
H3	Orange	Free potentiometer 3, high
A3	Orange	Free potentiometer 3, armature
L3	Orange	Free potentiometer 3, low
H4	Orange	Free potentiometer 4, high
A4	Orange	Free potentiometer 4, armature
L4	Orange	Free potentiometer 4, low
A1	Blue	Anode V16a
J1	Green	Cathode V16a , anode V16b
K1	Red	Cathode V16b
A2	Blue	Anode V17a
J2	Green	Cathode V17a, anode V17b
K2	Red	Anode V17b
A3	Blue	Anode V18a
J3	Green	Cathode V18a, anode V18b
K3	Red	Cathode V18b
A4	Blue	Anode V19a
J4	Green	Cathode V19a, anode V19b
K4	Red	Cathode V19b
SG SG SG	Black) Black) Black)	Signal ground; three commoned connections
V	Violet	Voltmeter input
R1 R2 R3 R4	White) White) White) White)	Four sockets for the connection of external recording device
IP1 OP2 IP2 OP2	Blue) Yellow) Blue) Yellow)	inputs and outputs to function generators or external equipment

SECTION 2

INSTALLATION

General

56. The SCD10 Analogue Computer is supplied as a fully-assembled and electrically set-up unit, and once the mains voltage selector panels have been set in accordance with the declared voltage of the mains supply, the computer is ready for use.
At time of factory test, all mains voltage selector panels will be set for a 240 volts input.

Setting of Mains Voltage Selector Panels

57. Four voltage selector panels will require setting, and all are readily accessible once the rear panel of the SCD10 is taken off. Two selector panels are associated with the main power supply AS1104, one with the 24 volt relay supply, and one with the heater supply unit. These selector panels can be set for a mains input of 110V or 220V ± 5, 10 and 20 volts.

A fifth selector panel is associated with the auto-transformer T1 which provides a choice of either 110 or 220 volts required to drive the fan motor.

SECTION 3

TEST PROCEDURE

General

58. The procedure described in this chapter is basically the production test to which all SCD10 Computers are subjected prior to despatch. It does not include the testing of the various units employed in the SCD10, these procedures being given in the individual handbooks covering these units.

Test Equipment Required

59. The following items of test equipment will be required:

(1) Avometer Model 8

(2) Oscilloscope (Solartron CD 1014.3)

(3) Patch cords and links.

Additionally an external ±100V stable reference supply will be required. Solartron Supply Sub-Unit AS756 is a suitable source.

Setting-up of Power Supplies

60. (1) Remove rear cover from computer.

(2) On all ten Amplifier Patch Panels insert links between socket SJ and SJ2, and OP and OP1.

(3) Set OUTPUT SELECTOR to OFF, HOLD switch to OFF, and function selector to POT. SET.

(4) Set MAINS switch to ON, and allow a five minute warm-up period.

(5) Monitor one of the 300 V supplies on the Avometer, and then on the built-in meter M1, checking that the two readings are within 2% (6V) of each other.

(6) On the mains supply unit AS1104 adjust the following controls to bring the +300 V, -300 V, and -200 V lines to their nominal levels within an accuracy of ±2% as registered on the built-in meter M1.

(7) Set METER switch successively to the +100 V and -100 V positions, and by observation of meter M1, check that these supplies stand at or near their nominal values.

(8) Set METER switch to the 24V position, and check that meter M1 registers 24V ±2V.

(9) Zero-set all outputs of the AA1054 amplifiers by connecting a double-beam oscilloscope between TP1 and earth on both upper and lower amplifiers. The waveforms displayed

should be adjusted symmetrically about earth by the adjustment of the potentiometers on the front panels.

(10) Connect the avometer between the internal -100 V supply and the external -100 V reference supply. (AS 756).

(11) At the back of the Control Panel, adjust RV1 for null indication on the Avometer.

(12) Repeat procedure given in sub-paragraphs (10) and (11) for the +100 V supply, adjusting RV2 which is located near RV1.

(13) Refit rear cover on computer.

Earth Free Potentiometers

61. NOTE

Each of the four free potentiometers must be tested individually.

(1) With the function selector at POT. SET and the OUTPUT SELECTOR at OFF, set the METER switch to position V.

(2) Patch +100V to socket H1, and -100V socket to L1. Connect the Avometer between sockets A1 and SG.

(3) Turn FREE POT 1 fully counter-clockwise, and check that a reading of -100V is registered on both the Avometer and internal meter M1.

(4) Rotate FREE POT 1 in a clockwise direction and check that the voltage registered on both meters varies smoothly from -100V (fully counter-clockwise) to +100V (fully clockwise).

(5) Repeat the procedure detailed in sub-paragraphs (2) to (4) for FREE POTS 2, 3 and 4.

(6) Remove all patch cords inserted for the purpose of this test.

Coefficient Potentiometers and Key Switches

62. (1) On the Control Panel, set the OUTPUT SELECTOR to the A1 position and coefficient potentiometer 1. A1 fully counter-clockwise.

(2) On Amplifier Patch Panel A1, set SUM/INT. selector to INT, and link +100V to socket H1, and socket A1 to socket IC.

(3) Rotate potentiometer 1. A1 in a clockwise direction, and check that the voltage registered on the internal meter M1 varies from 0V to -100V.

(4) Remove both links.

(5) On the Control Panel, rotate coefficient potentiometer 2. A1 fully counter-clockwise.

(6) On Amplifier Patch Panel A1, link -100V to socket H2; and socket A2 to socket IC.

(7) Rotate potentiometer 2. A1 in a clockwise direction, and check that the voltage registered on the internal meter M1 varies from 0V to ±100V.

(8) Repeat the procedure detailed in sub-paragraphs (1) to (7) for potentiometers 1. A2, 2. A2, 1. A3, 2. A3, 1. A4, 2. A4, 1. A5, 2. A5, 1. B1, 2. B1, 1. B2, 2. B2, 1. B3; 2. B3, 1. B4, 2. B4, 1. B5, and 2. B5 in turn.

(9) On the Control Panel set the METER selector to the NULL position, and the REFERENCE potentiometer to zero.

(10) Turn coefficient potentiometer 1. A1 fully counter-clockwise.

(11) Depress key switch associated with coefficient potentiometer 1. A1, and check that the voltage registered on the internal meter varies from 0V to +100V as potentiometer 1. A1 is rotated in a clockwise direction.

(12) Repeat the procedure detailed in sub-paragraphs (9) to (11) for potentiometers 2. A1, 1. A2 through 2. B5 in turn.

Input Resistors

63. (1) Set all SUM/INT switches on the ten Amplifier Patch Panels to SUM.

(2) On the Control Panel, set the METER switch to NULL, the OUTPUT SELECTOR to A1, and the REFERENCE potentiometer key switch to -100V.

(3) On all ten Amplifier Patch Panels,

patch +100V to the "1" socket (blue) placed immediately below the SJ1 socket (green).

(4) Adjust REFERENCE potentiometer for null-deflection on internal meter M1.

(5) Set OUTPUT SELECTOR successively to positions A2, A3, A4, A5, B1, B2, B3, B4 and B5, logging the voltages registered on meter M1 in each position.

(6) Patch +100V to the second "1" socket (blue), on each Amplifier Patch Panel and repeat the procedure detailed in sub-paragraph (5).

(7) Check that all logged voltage readings lie within ±200mV of the mean, i.e. the two extreme values must be within 400mV of each other.

(8) Making use of the four commoning sockets (white) on each Amplifier Patch Panel, patch from the arm socket (A1 - orange) of any coefficient potentiometer, to the ten upper "10" input sockets (blue) on each Amplifier Patch Panel. On the appropriate patch panel link +100 V to H1 of the coefficient potentiometer.

(9) Set the OUTPUT SELECTOR to the A1 position and adjust the coefficient potentiometer for null deflection on meter M1.

NOTE:
The reference potentiometer must not be moved from that setting arrived at in sub-paragraph (4).

(10) Set OUTPUT SELECTOR successively to positions A2, A3, A4, A5, B1, B2, B3, B4 and B5, logging the voltages registered on meter M1 in each position.

(11) Patch the arm socket (A1) of the coefficient potentiometer to the lower "10" input sockets on each Amplifier Patch Panel.

(12) Repeat the procedure detailed in sub-paragraph (10).

(13) Check that all logged voltage readings lie within ±200 mV of the mean, i.e. the two extreme readings must be within 400 mV of each other.

(14) Remove all patch cords and links.

Feedback Capacitors

64. (1) On the five "A" Amplifier Patch Panels set all SUM/INT selectors to INT. Patch from the arm socket (A1) of any coefficient potentiometer to a "1" input socket (blue) on each of the five "A" Amplifier Patch Panels. Link socket H1 of the coefficient potentiometer to +100 V.

(2) Set METER selector to NULL and OUTPUT SELECTOR to OFF.

(3) Depress key switch associated with the coefficient potentiometer and adjust the potentiometer so that meter M1 registers 10 V.

(4) Set METER selector to "V" position.

(5) Set the function selector to COMPUTE, after ten seconds has elapsed, going to HOLD.

(6) With the aid of the OUTPUT SELECTOR switch monitor the output voltages of all "A" amplifiers.

(7) Monitor between the five amplifier output sockets (OP) with the Avometer, and check that the difference between any two outputs is not greater than 1 V.

(8) Repeat the procedure detailed in sub-paragraphs (1) to (7) for the five "B" amplifiers, this time adjusting the potentiometer so that meter M1 registers 1V. Refer sub-paragraph (3).

(9) Remove all patch cords and links inserted for the purpose of this test.

Repetitive Operation

65. (1) Set the function selector to each of the three REP. positions in turn, checking that the COMPUTE periods are approximately one, two and five seconds and that the reset (PROBLEM CHECK) period is approximately one second.

Reference Potentiometer Setting

66. (1) Set the dial REFERENCE potentiometer to 0.02.

(2) Link +100V to the H1 socket of any coefficient potentiometer, and patch the arm socket (A1) to a "1" input socket of an "A" amplifier.

(3) Set the SUM/INT selector on the "A" amplifier to INT.

(4) Set the function selector to POT. SET., the METER selector to NULL, and the OUTPUT SELECTOR to OFF.

(5) Adjust the coefficient potentiometer for NULL deflection on meter M1.

(6) Set function selector to COMPUTE, and after exactly 50 seconds, check that the amplifier output voltage is within ±1 V of 100 V.

(7) If the reading obtained is outside these limits, reset the position of the reference potentiometer dial on the spindle so that the condition specified in sub-paragraph (6) is obtained.

(8) Remove link and patch cord inserted for the purpose of this test.

Leakage and Grid Current

67 (1) At the Control Panel set the function selector to PROBLEM CHECK.

(2) On the Amplifier Patch Panel set all SUM/INT selectors to INT.

(3) On Amplifier Patch Panel A1 remove link between SJ and SJ2, and connect an 0.01 μF polystyrene capacitor, tolerance ±2%, between socket SJ and OP.

(4) Set the function selector to COMPUTE, and after 100 seconds has elapsed monitor the output of the amplifier, which should be less than 1 V.

(5) Remove capacitor and reinsert link between SJ and SJ2.

(6) Repeat the procedure detailed in sub-paragraphs (3) to (5) for the nine remaining amplifiers.

Overload

68. (1) Set the function selector to COMPUTE, and the OVERLOAD switch to ON.

(2) On the panel of any amplifier, rotate the amplifier SET ZERO control quickly so that the neon glows.

(3) Check that the red OVERLOAD indicator lamp, on the Control Panel lights at the same time as the neon, and that the computer is brought automatically to HOLD as evidenced by the lighting of the red HOLD indicator lamp on the Control Panel.

(4) Re-balance the amplifier.

SECTION 4

BREAKDOWN INSTRUCTIONS

Removal of Badge Panel

69. The Badge Panel carries the Auxiliary Patch Panel and the Solartron name-plate, and is located immediately below and in the same plane as the Control Panel.

(1) Remove four 2BA hexagonal-headed bolts fixing the Badge Panel.

(2) Withdraw the Badge Panel from the cabinet. There are no cables attached to this panel.

Removal of Patch Panel

70. (1) Remove the Badge Panel following the directions given in paragraph 69.

(2) Withdraw the four 2BA hexagonal-headed bolts securing the Patch Panel.

(3) Ease Patch Panel partially out of cabinet in an upward and forward direction to gain access to cableform connectors at rear.

(4) Disconnect six cableform connectors from rear of Patch Panel.

NOTE:
On a SCD 10 fitted with two servo multipliers eight cableform connectors will require disconnection.

(5) Lift Patch Panel clear of cabinet.

Removal of Control Panel

71. (1) Remove upper rear cover from back of cabinet within limit allowed by length of mains lead to fan.

(2) Disconnect six electrical connectors from the rear of the Control Panel.

(3) Withdraw four 2BA hexagonal-headed fixing bolts from the front of the Control Panel, and withdraw the panel from the front of the cabinet.

NOTE:
Since the panel will drop when the last bolt is removed, a second person should support the panel in its normal position from the back of the cabinet whilst the bolts are being removed from the front.

Removal of Servo Multiplier Units

72. (1) Release two captive screws at front of servo multiplier, and pull unit clear of rack by handle.

Removal of Amplifier Racks

73. (1) Remove bottom cover plate from rear of cabinet.

(2) Release two captive bolts on each of the six sub-units carried in the amplifier rack, and withdraw these sub-units from front.

(3) Disconnect socket SKA or SKB as appropriate from rear of amplifier rack.

(4) From front of cabinet remove four 4BA hexagonal-headed bolts.

(5) Push the appropriate amplifier rack forward from the back of the cabinet, and withdraw from front.

Adjustment of Power Supply AS 1104

74. Output voltage adjustment on the +300 V and -200 V HT lines is made available on the front panel by a potentiometer. Monitoring points for these lines is also provided by jack-sockets. Suitable engraving on the panel indicates the respective HT lines to which these controls refer.

Two mains. tapping panels are provided at rear of the unit, one for HT supplies, and one for LT supplies. Both these panels must be adjusted to suit the mains supply in use.

Mains input is by means of a Plessey 6-way plug and socket; all power outputs being taken from two identical 15-way sockets SK1 and SK2. These plugs and sockets are also located at the rear of the unit.

Removal of the AS 1104 can be effected by disconnecting all connecting plugs and sockets from the rear of the unit. The four hexagonal-headed screws located at the four corners of the front panel should now be removed, and the whole unit withdrawn from the front of the cabinet.

Reference to the power supply manual will give any further details required.

COMPONENTS LIST

RESISTORS

Circuit Ref.	Value Ohms	Tol. %	Rating Watts	Solartron Part No.	Manufacturer & Type	
R1	10K	10	$\frac{1}{4}$	226337	Erie	16 Carbon
R2	100	10	$\frac{1}{4}$	226313	Erie	16 Carbon
R3	220K	10	$\frac{1}{4}$	226353	Erie	16 Carbon
R4	82K	10	$\frac{1}{4}$	226348	Erie	16 Carbon
R5	82K	10	$\frac{1}{4}$	226348	Erie	16 Carbon
R6	1K	10	$\frac{1}{4}$	226325	Erie	16 Carbon
R7	1M	10	$\frac{1}{4}$	226361	Erie	16 Carbon
R8	1M	10	$\frac{1}{4}$	226361	Erie	16 Carbon
R9	5.1K	2	$\frac{3}{4}$	224459	Painton	74 H.S.
R10	5.1K	2	$\frac{3}{4}$	224459	Painton	74 H.S.
R11	2.4K	2	$\frac{3}{4}$	224451	Painton	74 H.S.
R12	4.7K	10	$\frac{1}{4}$	226333	Erie	16 Carbon
R13	100	10	$\frac{1}{4}$	226313	Erie	16 Carbon
R14	2.2M	10	$\frac{1}{4}$	226365	Erie	16 Carbon
R15	11K	2	1/8	221150	Erie	109 H.S.
R16	43K	2	1/8	221164	Erie	109 H.S.
R17	270K	2	$\frac{3}{4}$	224500	Painton	74 H.S.
R18	3.3M	2	$\frac{3}{4}$	224526	Painton	74 H.S.
R19	4.7K	10	$\frac{1}{4}$	226333	Erie	16 Carbon
R20	100	10	$\frac{1}{4}$	226313	Erie	16 Carbon
R21	220K	10	$\frac{1}{4}$	226353	Erie	16 Carbon
R22	100	10	$\frac{1}{4}$	226313	Erie	16 Carbon
R23	56K	1	1/8	221067	Erie	109 H.S.
R24	6.8K	1	1/8	221045	Erie	109 H.S.
R25	100	10	$\frac{1}{4}$	226313	Erie	16 Carbon
R26	820K	1	$\frac{3}{4}$	224312	Painton	74 H.S.
R27	1.5K	10	$\frac{1}{4}$	226327	Erie	16 Carbon
R28	750K	2	$\frac{3}{4}$	224511	Painton	74 H.S.
R29	2.2K	5	6	239041	Welwyn	AW 3112 W.W.
R30	100	10	$\frac{1}{4}$	226313	Erie	16 Carbon
R31	39K	10	$\frac{1}{4}$	226344	Erie	16 Carbon
R32	100K	2	$\frac{3}{4}$	224490	Painton	74 H.S.
R33	130K	1	$\frac{3}{4}$	224294	Painton	74 H.S.
R34	100	10	$\frac{1}{4}$	226313	Erie	16 Carbon
R35	2.2K	10	$\frac{1}{4}$	226329	Erie	16 Carbon
R36	220K	10	$\frac{1}{4}$	226353	Erie	16 Carbon
R37	100	10	$\frac{1}{4}$	226313	Erie	16 Carbon
R38	18K	5	6	235940	Painton	302 A W.W.
R39	1.2K	10	$\frac{1}{4}$	226326	Erie	16 Carbon
R40	100	10	$\frac{1}{4}$	226313	Erie	16 Carbon
R41	1M	1	$\frac{1}{4}$	224314	Painton	74 H.S.
R42	820K	1	$\frac{3}{4}$	224312	Painton	74 H.S.
R43	100	10	$\frac{1}{4}$	226313	Erie	16 Carbon
R44	3M	1	$\frac{3}{4}$	N22255	Welwyn	C 23 W.W.
R45	100K	1	6	238897	Painton	402 A W.W.