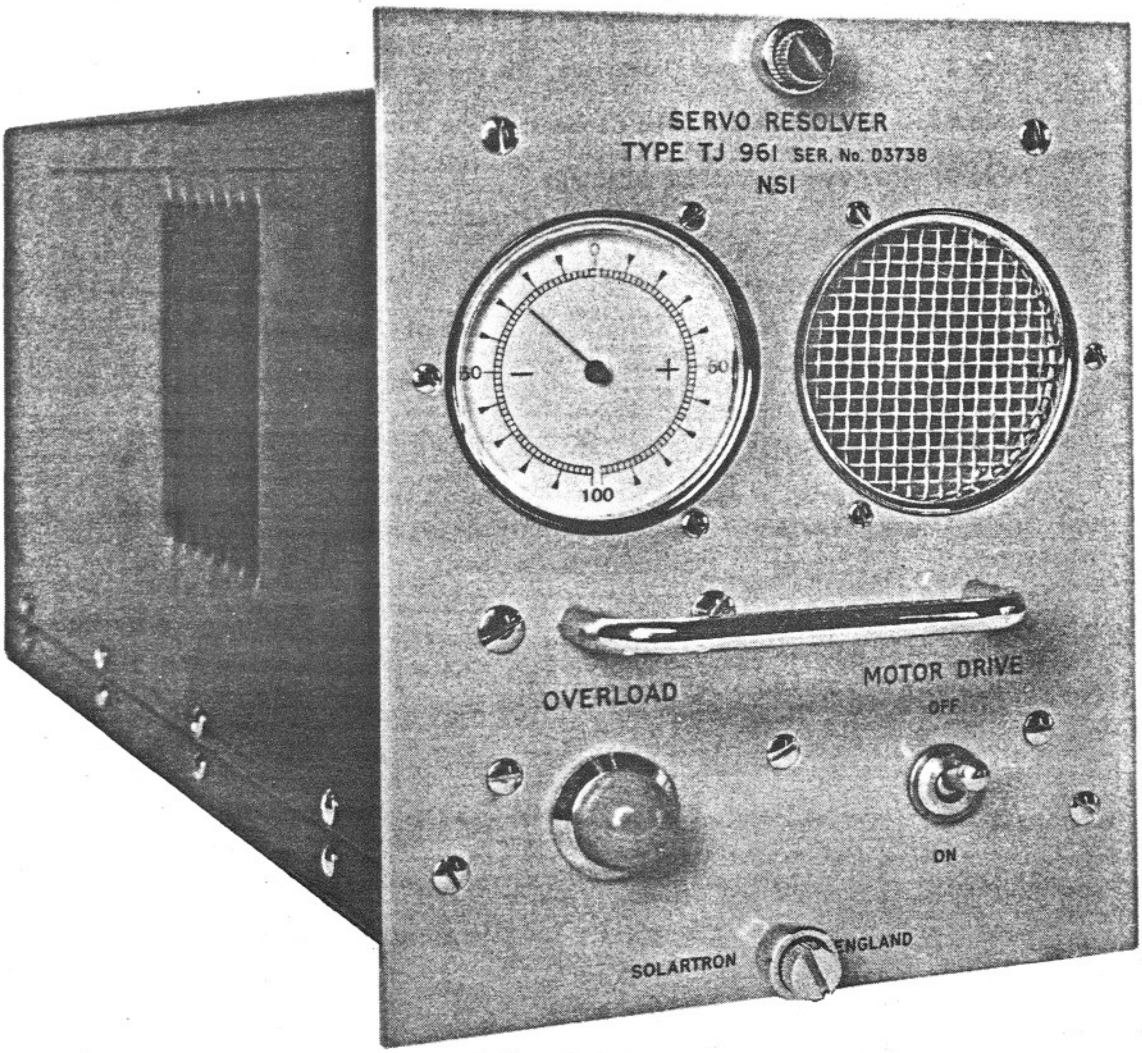


Fig. 1 Servo Resolver Type TJ961 Frontispiece

## SECTION 1

## INTRODUCTION

1. The Solartron TJ725 Servo Multiplier is a general purpose, potentiometer-type multiplier for use with electronic analogue computers. It incorporates a six-section linear potentiometer to permit the multiplication of five quantities by a common multiplier. With the exception of the input stage, the servo amplifier and its power supply system are completely transistorised. The TJ961 Servo Resolver is driven by an identical servo system but is provided with two sine-law graded potentiometer sections to provide sine and cosine functions of the shaft angle. Additionally, the TJ961 is fitted with two linear multiplying potentiometer sections.

2. Both types of servo unit have the same dimensions and may be used as a bench instrument, or carried in a Servo Mounting Unit Type TX926, which provides for mounting up to three units in a standard 19 inch rack.

## SECTION 2

## SUMMARY OF TECHNICAL DATA

3. Static Accuracy

With potentiometer centre - taps earthed ±0.5%

With zero input ±0.25%

Dynamic Accuracy

Additional error due to dynamic response ±0.5%

Amplitude Capabilities

Linear operation up to approximately 10c/s full amplitude. Accepting some error full amplitude can be obtained up to 15c/s.

Phase Shift

At 10c/s full amplitude, less than 1°.

Transient Response

Rise or fall time from zero to full-scale not greater than 30 milliseconds with approximately 5% overshoot.

Noise Level

Approximately 0.25% peak-to-peak.

Temperature Limitation

Maximum ambient temperature for satisfactory operation 40°C approximately.

Drift at 40°C 100mV approximately.

Power Requirements

90 - 130/200 - 240 volts, 40 - 60c/s, single phase.

Power Consumption

70VA.

Overall Dimensions and Weight

| | | |
|---|---|---|
| Height | 7 in. | 17.8cm |
| Width | 5.6 in. | 14.2cm |
| Depth | 17 in. | 43.2cm |
| Weight | 17 lb | 4.7kg |

SECTION 3

INSTALLATION AND OPERATION

## INSTALLATION

4. The equipment is supplied as a completely assembled unit ready for installation. At time of factory test, the mains voltage selector panel will have been set for an input of 230 volts, and a 500mA fuse cartridge fitted in FS2 carrier. External stabilised reference supplies of ±100 volts each at 4.0mA must be available for the operation of the unit.

(1) Remove top and bottom covers. Set mains input voltage selector.

(2) Check that the mains fuse FS2 is continuous and of the correct rating.
110V range mains input - 1A
220V range mains input - 500mA.

(3) Check that the printed circuit fuse FS1 is continuous and is rated for one ampere.

(4) Check that the potentiometer fuses are continuous and each have a resistance of approximately 150 ohms.

Note
The Servo Multiplier TJ725 contains six potentiometer fuses (FS3-FS8), whilst the Servo Resolver TJ961 contains seven potentiometer fuses (FS3-FS9).

(5) If the unit is to be carried in a Servo Mounting Unit Type TX926, on the MAINS IN panel LK1 link the pins designated VIA RACK. If the unit is to be used bench-mounted, link the pins designated DIRECT on the MAINS IN panel.

(6) If the unit is to be bench-mounted, connect the mains input lead at plug PL1, pin A-line, pin B-neutral, and pin C-earth.

(7) Refit top and bottom covers.

(8) Apply reference voltages to plug PL2 thus:-

| | |
|---|---|
| Pin 1 | -100V |
| Pin 2 | +100V |
| Pin 3 | Mid-point of reference voltage (signal ground). |

## OPERATION

5. (1) Apply mains voltage to unit.

(2) Set MOTOR DRIVE switch to ON. Check that the OVERLOAD indicator lamp lights, and is extinguished some 30-60 seconds after the MOTOR SWITCH is closed.

(3) The servo should now be ready for operation.

(4) Should the servo spin after the OVERLOAD indicator lamp goes out, set MOTOR DRIVE switch to OFF and confirm that the ±100V reference supplies are applied to the servo, and that the fuse (FS3) in the feedback potentiometer wiper is intact.

(5) Should the servo oscillate after the OVERLOAD indicator lamp goes out, set MOTOR DRIVE switch to OFF, and check that the ±100V reference supplies are applied to PL2 with correct polarity.

| | |
|---|---|
| Pin 1 | -100V |
| Pin 2 | +100V |
| Pin 3 | Mid-point of reference. |

(6) Set MOTOR DRIVE switch to On, check that the OVERLOAD indicator lamp lights and is extinguished some 30-60 seconds after the MOTOR SWITCH is closed.

(7) The servo is now ready for operation.

### Operational Precautions

6. (1) The arms of the potentiometers must not be earthed since the resultant high current would destroy the potentiometers. Some protection is provided by the 10mA fuse wired in each arm.

(2) The voltage applied across any slave potentiometer must not exceed 300 volts.

(3) The voltage applied across any section of the tapped potentiometer must not exceed 30 volts.

### Servo Accuracy Factors

7. (1) The ±100V reference supplies must be balanced to earth within 0.1% if static errors are not to be introduced.

(2) The arms of the slave potentiometers must each be loaded with a resistance of one megohm to an accuracy of 5%. The other end of the loading resistor being taken to near earth potential, i.e. computer amplifier input.

(3) The linear potentiometer centre-taps must be earthed, and the potentiometer fed with push-pull inputs if the greatest accuracy is to be obtained. The servo can be operated with non-earthed centre-taps and single-ended inputs in circumstances where an error of 0.5% is admissable.

### Transient Performance

8. The transient performance of the servo system can be adjusted according to the application in which the servo is to be used. At time of factory test, the servo is set-up to a 5% overshoot. The rise time can be increased or alternatively the overshoot reduced by adjustment of variable resistor RV8 in accordance with the directions given in sub-paragraphs (1) to (3) following.

Note
Variable resistor RV8 must not be adjusted during the normal operation of the equipment, but only when the transient performance of the servo is being checked or reset to a different overshoot value.

(1) Apply a 1c/s square wave to the input (pin 18, PL3) at the amplitude at which the servo is to be used.

(2) Connect a d.c. potential across a slave potentiometer, and observe the output from the arm of the potentiometer on an oscilloscope.

(3) From the rear panel of the unit, adjust RV8 to give the required performance as measured on the oscilloscope.

Note
Instability may be caused if the damping is reduced to give more than 15% overshoot.

### Multiplication

9. Multiplication is performed with the linear potentiometers, six of which are fitted on the TJ725, and designated the feedback potentiometer and slave potentiometers A, B, C, D and E.

Slave C is provided with nine tappings for the connection of external padding resistances if it is desired to give the winding a non-linear characteristic for the generation of discontinuous functions. The multiplier, alternatively designated the input voltage $V_I$, is applied at pin 18 on plug PL3, and through the servo system, drives the shaft of the potentiometer gang so that the wiper of the feedback potentiometer comes to rest at a position which is proportional to the input voltage $V_I$. If a push-pull voltage $V_p$ is applied across slave potentiometer A, then the output voltage from the arm of slave A will be proportional to the product of the input voltage and the voltage applied across slave potentiometer A, or

$$V_o \propto V_I \, V_p.$$

Push-pull inputs to the slave potentiometers are necessary if the multiplier is to accept inputs of both signs for $V_I$ and $V_p$ and to provide an output voltage Vo of the correct sign, i.e. four-quadrant operation. The extremities, tappings and arms of all linear potentiometers are terminated at plug PL3 as listed in Table 1 for the TJ725 multiplier.

TABLE 1

TJ725 SIGNAL CONNECTOR PIN ASSIGNMENTS

| POTENTIOMETER | PL3 PIN NUMBER | | | |
|---|---|---|---|---|
| | HIGH | CENTRE-TAP | ARM | LOW |
| Slave A | 32 | 16 | 31 | 15 |
| Slave B | 30 | 29 | 28 | 27 |
| Slave C | 26 | 10 | 25 | 24 |
| Slave D | 23 | 22 | 21 | 5 |
| Slave E | 20 | 4 | 19 | 3 |

Note
Slave C is provided with eight tappings excluding the centre-tap. These are connected to PL3 thus:-

| Tap No. | PL3 Pin No. |
|---|---|
| 2 | 14 |
| 4 | 13 |
| 5 | 12 |
| 7 | 11 |
| 10 | 9 |
| 11 | 8 |
| 13 | 7 |
| 14 | 6 |

## Sine and Cosine Functions

10. The TJ961 resolver is provided with two sine/cosine potentiometers. Each of these components will give an output of:-

$$\sin\left(\frac{V_I\pi}{V_R}\right)V_p$$

$$\cos\left(\frac{V_I\pi}{V_R}\right)V_p$$

where $V_I$ is the input voltage determining the potentiometer shaft position.

$V_p$ is the voltage applied across the sine/cosine potentiometer.

$V_R$ is the reference voltage.

Additionally, the TJ961 resolver is fitted with two linear multiplying potentiometers. The connections to the sine/cosine and linear potentiometers are made at plug PL3 mounted on the rear wall of the unit, and are listed in Tables 2 and 3.

TABLE 2

TJ961 SIGNAL CONNECTOR PIN ASSIGNMENTS

SINE/COSINE POTENTIOMETERS

| POTENTIOMETER | PL3 PIN NUMBER | | | | |
|---|---|---|---|---|---|
| | V+ | V- | EARTH | SIN | COS |
| Slave D | 23 | 5 | 17, 22 | 28 | 21 |
| Slave E | 20 | 3 | 1, 4 | 19 | 27 |

TABLE 3

TJ961 SIGNAL CONNECTOR PIN ASSIGNMENTS

LINEAR POTENTIOMETERS

| POTENTIOMETER | PL3 PIN NUMBER | | | |
|---|---|---|---|---|
| | HIGH | CENTRE-TAP | ARM | LOW |
| Slave A | 32 | 16 | 31 | 15 |
| Slave C | 26 | 10 | 25 | 24 |

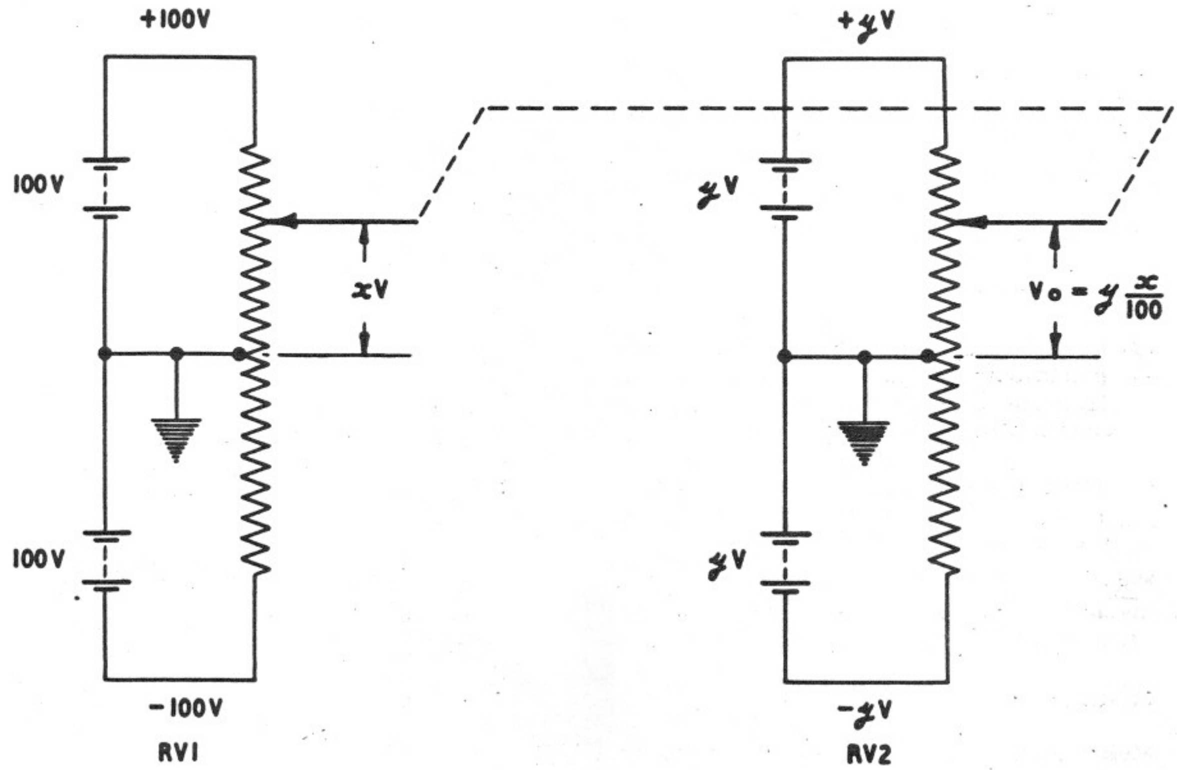


Fig. 2 Electrical Method of Multiplication

## SECTION 4

## PRINCIPLES OF OPERATION

### Multiplication by Electrical Method

11. Refer Fig. 2.

An accepted electrical method of multiplication is by ganged linear potentiometers. A fixed reference voltage is applied across potentiometer RV1, the mid-point of the reference potential and the centre-tap of the potentiometer being connected to earth. A reference potential of 100 volts is employed on the TJ725 and TJ961. A voltage y, proportional to the quantity to be multiplied is applied across potentiometer RV2, the mid-point of this voltage and the potentiometer centre-tap again being earthed. If the arm of potentiometer RV1 is now set-up to a voltage x proportional to the multiplier, then providing that the potentiometer gang alignment is precise, the arm of potentiometer RV2 will take-up a coincident position to that of RV1. The position of the arm on potentiometer RV1 can be defined by the ratio $\frac{x}{100}$, which since the potentiometers are identical and ganged, also defines the position of the arm on RV2. Bearing in mind that the voltage applied across potentiometer RV2 is yV, the output voltage Vo picked-off by the arm of RV2 must be equal to $y\frac{x}{100}$, or since the reference voltage though a constant need not necessarily be 100 volts.

$$Vo = xyk$$

where k is a proportionality constant.

### Sine/Cosine Functions

2. Refer Fig. 3.

The TJ961 resolver is fitted with two sine/cosine potentiometers in addition to two linear multiplier potentiometers. The sine/cosine potentiometers are wound with sine-law graded windings, and fitted with two electrically isolated arms displaced from each other by an angle of 90°. Potentiometer RV1 is wound with a linear winding and ganged to RV2. It is in all respects identical with potentiometer RV1 shown in Fig. 2, but to simplify diagrammatic presentation it is drawn in its circular physical form in Fig. 3. Though the electrical sweep angle of RV1 potentiometer wiper is restricted to 355°, the mechanical sweep angle is unlimited since no physical stops are fitted on the potentiometer track.

A fixed reference potential, 100 volts in the TJ961, is applied across RV1, with the mid-point of the reference potential and the

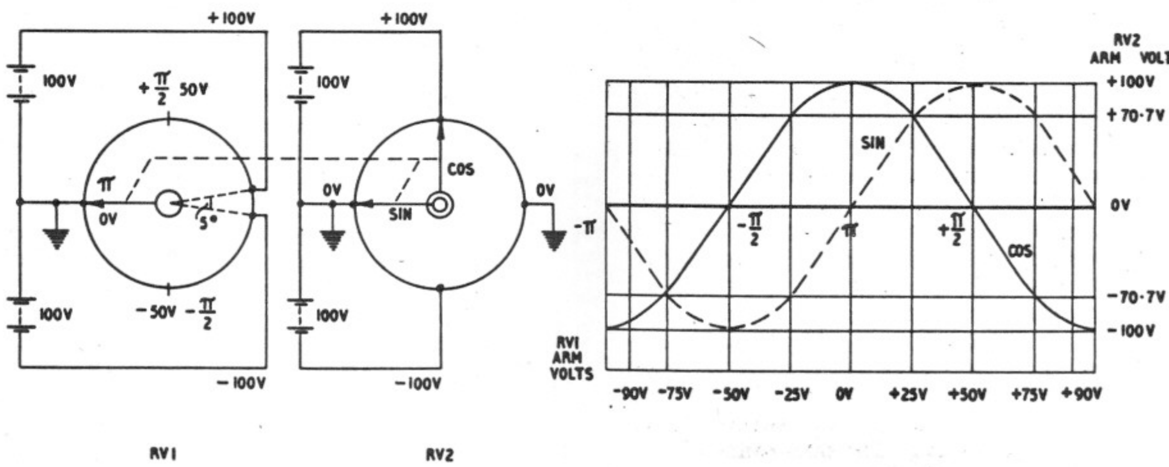


Fig. 3 Derivation of Sine and Cosine Functions

centre-tap of the winding connection to earth. A potential of 100 volts is applied across potentiometer RV2, with the mid-point of the supply and the diametrically opposed winding centre-taps connected to earth. Assuming that the ganged shafts of RV1 and RV2 are initially in the positions shown in Fig. 3, then RV1 arm potential is zero, and the potentials of the sine and cosine arms of RV2 are respectively zero and +100 volts. If now the arm of RV1 is set-up to +50 volts by rotation in a clockwise direction, the potential of the sine and cosine arms will be +100 volts and zero volts respectively. Similarly, a counter-clockwise rotation of RV1 from the zero volts position to set-up -50 volts on the arm will bring the potentials of the sine and cosine arms to -100 volts and zero volts respectively. Considering the sine and cosine arms as vectors rotating through $+\pi$ and $-\pi$ radians from the initial positions, then the output from those arms will be of sinusoidal from as shown by the curves in Fig. 3. The expressions for the outputs from the sine and cosine arms can be written thus:-

$$\sin\left(\frac{\pi x}{100}\right)xy$$

$$\cos\left(\frac{\pi x}{100}\right)xy$$

| | | | |
|---|---|---|---|
| where | x | = | RV1 arm voltage |
| | y | = | voltage applied across RV2 |

Servo System

13. The ganged potentiometers in the TJ 725 multiplier and TJ961 resolver are motor driven by a servo system, a block schematic diagram of which is given in Fig. 4. The ±100 volts reference supply is connected across the feedback potentiometer, which corresponds to RV1 in Figs. 2 and 3. The existing voltage on the arm of the feedback potentiometer is applied to one input of a voltage comparator. The voltage required to be set-up on the arm of the feedback potentiometer, hereafter called the input voltage, is applied to the second input of the comparator. The difference or error voltage between the two inputs to the comparator is applied as a correcting signal to a servo amplifier to drive the servo motor in such a direction as to reduce the error voltage to zero, or in other words, to set the feedback potentiometer arm voltage to the input voltage. It will be seen from the block diagram that there are two input channels to the servo amplifier. The d.c. channel is fed from the error voltage developed across the resistive components of the voltage comparator, whilst the phase-correction channel is fed from the capacitive components. The d.c. impedance converter stage, comprising a valve and one transistor, serves to match the high impedance of the comparator resistors to the low impedance of the transistorised servo amplifier. The application of an input voltage to the comparator will cause a current to flow in resistors R1 and R2, the magnitude and direction of which current will be proportional to the difference or error voltage between the input voltage and the existing voltage on the arm of the feedback potentiometer. This current will develop across resistor R2 a voltage proportional in magnitude and polarity to the error voltage, which is applied to the servo amplifier via the d.c. impedance converter stage. The resultant output from the amplifier will drive the servo motor in such a direction as to reduce the error voltage. The servo motor drive system comprises four stages, namely power amplifier, first current control stage, paraphase amplifier and second current control stage. The power amplifier, driven by the outputs of the d.c. and phase correction channels, feeds the paraphase amplifier and first current control stage. The paraphase amplifier effects a phase reversal and drives the second current control stage with its reversed phase output. Each current control stage also effects a phase reversal. The outputs from these four stages are employed to control the current through transistors X17, X18, X19 and X20. In the quiescent condition, each pair of transistors (X17-X18, X19-X20) passes a current of 300 milliamperes. Assuming that a negative signal appears at the input of the power amplifier the outputs from the four stages will have the polarity shown in Fig. 4, with the result that transistors X17 and X20 will cut-off, and a drive current will flow through the motor armature and transistors X18 and X19 in the direction shown.



SVP
M

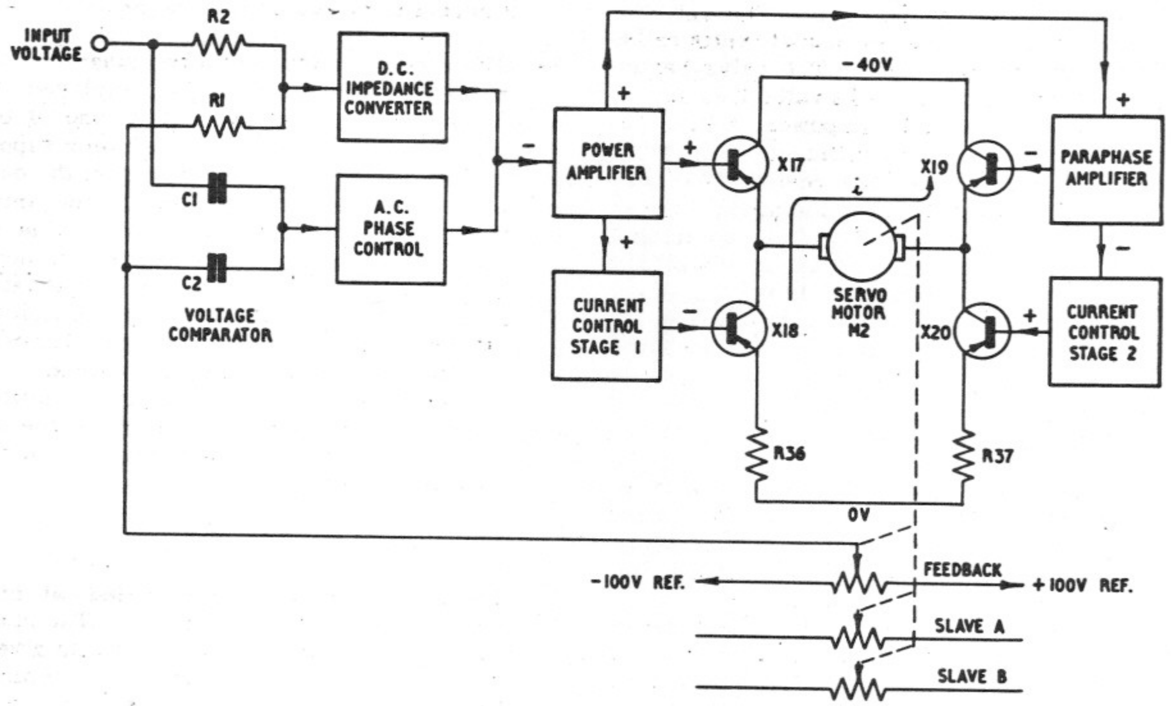


Fig.4 Servo Multiplier Type TJ725 - Block Diagram

## SECTION 5

## PHYSICAL DESCRIPTION

### General

14. The unit is built on an inverted tray type chassis with the larger components, viz., transformers, smoothing capacitors, fuse board and transistor heat sink, mounted on top. The smaller components are carried on two printed circuit boards fitted beneath the deck of the chassis. The heat sink which carries all eight power transistors and two of the intermediate power transistors is built as an open-ended two-piece rectangular section with the transistor fixing nuts and connections applied from the outside of the sink. A small blower unit is mounted at one end of the sink, air inlet and outlet being taken via wiremesh covered apertures let into the panel and rear wall of the instrument. All connections to the unit are made at three rear-mounted plugs. Cover plates are fitted.

### Panel Fittings

15. The panel of the unit carries one control and one signal lamp.

SW1 MOTOR DRIVE ON/OFF Switch
LP1 OVERLOAD indicator lamp (red)

Additionally, a potentiometer arm position pointer is provided, which sweeps through the electrical angle of 355$^{o}$ over a dial scaled from 0 to ±100.

## CIRCUIT DESCRIPTION

Circuit Diagram Fig. 8

### Voltage Comparator Stage

16. The input voltage and feedback potentiometer (RV7) arm voltage are compared for error by close tolerance one megohm resistors (R1, R2) and 1500pF capacitors (C1, C2). The input to the d.c. channel is taken from the resistors, whilst the changing voltage across the capacitors is differentiated to provide an input to the a.c. channel in the manner described in paragraph 13.

### D.C. Impedance Converter

17. This stage, employing a pentode valve V1 and one transistor X6, serves to match the high output impedance of the comparator stage to the relatively low impedance of the

transistor power amplifier. The valve is connected across the -40 and +12 volts rails, as a cathode follower. The valve heater is energised from the 12 volts d. c. supply provided by the built-in power pack. The output of the valve amplifier is taken from across the cathode load resistor R17 and applied between base and emitter of the transistor amplifier X6. The bias applied to the base/emitter circuit by the potential divider RV1, R18 controls the d.c. level of the servo system. Output to the succeeding power amplifier stage is taken from the collector load resistor R76.

Power Amplifier

18. The power amplifier stage employs three transistors X8, X7 and X16. The output from the d. c. impedance converter is applied directly (without attenuation) to the base of transistor X8 so that the overall gain of the d.c. channel is of the order of 60 times. Negative feedback is taken from the emitter of the power transistor X16 to the input stage via resistor R26. The quiescent output voltage at the emitter of X16 is -21 volts, with a maximum swing of ±14 volts about this mean value. Transistor X7 is fitted with a split collector load, the voltage developed across resistor R24 providing the drive to the power transistor X16, whilst resistor R25 determines the minimum output voltage of the stage. The inputs to the Paraphase Amplifier and first Current Control Stage are taken at high level from the emitter of transistor X16.

A. C. Phase Control Stage

19. The phase-correcting input voltage is developed across resistor R3 and amplified in a four-stage amplifier employing transistors X1, X2, X4 and X5. The a. c. signal appearing at the collector of X4 is divided down by the potential divider R13, RV8, R14 to inject a negative feedback voltage into the emitter circuit of X2 via transistor X3 and the common emitter resistor R11. Variable resistor RV8 determines the amplitude of the negative feedback voltage applied to transistor X3 and thus controls the a. c. gain of the stage. The drive to the power amplifier is coupled via C7 and R19 to the base of transistor X8. An additional in-phase drive is taken from the collector of X5 and applied to the power amplifier at the emitter of X7. Variable resistor RV2 controls the amplifier gain in the negative direction.

Current Control Stage 1

20. The circuit consists of a two stage transistor amplifier which is employed to control the current passed by one of the power transistors (X18) in the motor supply circuit. The stage is driven from the output of the Power Amplifier, the input voltage being dropped to a suitable value by the series resistor R27. The d. c. level of the amplifier is determined by resistor R28. Overall negative feedback is applied via resistor R29, and the effective gain of the stage is approximately 0.2 times. It will be noted that the two stage amplifier produces a phase-reversal between the input to the base of X9 and the output at the emitter of X10.

Paraphase Amplifier

21. The Paraphase Amplifier is fed at high level from the Power Amplifier. The stage has a gain just in excess of unity to give a quiescent output of -21 volts. It employs the same basic circuitry as the Power Amplifier stage but the values of the input and feedback resistors are suitably modified to give the reduced gain required. As its name implies the function of the stage is to provide a phase-reversed input to power transistor X19 in the motor supply circuit, and to the second Current Control Stage.

Current Control Stage 2

22. This circuit is in all respects similar to that employed in Current Control Stage 1 as described in paragraph 20. It is driven by the phase-reversed output from the Paraphase Amplifier, and itself effects a phase-reversal between the input to the base of X12 and the output at the emitter of X11.

Power Control Stage

23. The Power Control Stage consists of four power transistors X17-X20 which are employed to control the magnitude and direction of the drive current applied to the servo motor. In the quiescent condition, the d.c. resistances of power transistors X18 and X20 are regulated by Current Control Stages 1 and 2 respectively, so as to pass currents of 300mA each. The d. c. resistances of power transistors X17 and X19 in this condition are of such values as to provide a low impedance path for these currents with the result that no drive is

applied to the servo motor. Assuming that an input voltage is applied to the unit so as to cause a negative signal to appear at the input to the Power Amplifier, the polarity of the resultant voltages appearing at the outputs of the Power and Paraphase Amplifiers, and Current Control Stages 1 and 2 will be as shown on the block schematic diagram, Fig. 4. The collector currents passed by transistors X18 and X19 will thereon increase, whilst the currents passed by X17 and X20 will be correspondingly decreased, causing a drive current to pass through the servo motor armature in the direction shown on the block diagram. Similarly, an input voltage of opposite polarity will apply a reversed drive to the servo motor.

## Power Supply System

### General

24. The unit has a built-in power pack, which from a mains input provides regulated supplies at -40 and +12 volts d.c. for the operation of the amplifiers, and the servo and fan motors.

### Input Circuit

25. The mains transformer T1 is provided with split primary windings capable of series/parallel connection to accommodate a mains input of 90, 100, 105, 110, 115, 120 or 130 volts in the lower voltage range, or 200, 210, 215, 220, 225, 230 or 240 volts in the higher voltage range. The primary winding is protected by fuse FS2 rated for three amperes. When the unit is mounted in the rack type TX926, mains input is applied at pin 6 (line) and 7 (neutral) on plug PL2. If used as a bench-mounted unit, input is applied at pins A (line) and B (neutral) on plug PL1. It should be noted that the mains input is routed to transformer T1 via link panel LK1, the VIA RACK pins of which must be linked if the input is applied at plug PL2. If input is applied at PL1 then the DIRECT pins on LK1 must be connected.

### +12 Volts D.C. Supply

26. The supply is stabilised by a feedback transistor amplifier which is employed to regulate the impedance of the series element, a power transistor. The output from a 14 volts secondary winding on transformer T1 is rectified by the bridge connected germanium diodes MR2, MR4, MR5 and MR6. Smoothing is effected by capacitor C21. Transistors X27 and X28 are connected as a differential amplifier with the signal input from the sampling chain (R69 RV6, R70) applied to the base of X28. The reference voltage is provided by the zener diode X32, which holds the base potential of X27 five volts positive with respect to the zero volts rail. The value of resistor R63 is such that the current passed by the zener diode is 5mA. The output from the differential amplifier is taken from the collector of transistor X27 and applied to the base of an emitter-follower stage (X30), which in turn drives the series transistor X23. Potentiometer RV6 permits the system output level to be accurately set to 12 volts. Since the output impedance of the stabiliser increases with frequency, capacitor C25 is connected in parallel with the load so as to reduce the output impedance at rising frequencies.

### -40 Volts D.C. Supply

27. The supply is stabilised by a feedback transistor amplifier with a variable resistance series element provided by two paralleled power transistors. The output from a 55 volts secondary winding on transformer T1 is rectified by the bridge-connected germanium stack MR1, and applied to a choke input filter circuit L1, C20. The supply is protected by fuse FS1 rated for one ampere. The signal to the input amplifier X29 is taken from the sampling chain R71, R74 connected across the -40 volts and stabilised +12 volts rails, the latter serving as the reference potential. The output from the collector of X29 is successively amplified by two emitter-follower stages X26 and X25, the latter being a power transistor. The coupling between X26 and X25 is made via three series-connected zener diodes X31, X33 and X34.

The drive to power transistors X22 and X24, paralleled in the positive side of the supply to form the variable series resistance, are driven from the emitter of X25. Resistors R58 and R60 connected in the collector circuits ensure that the line current drawn from the supply is shared approximately equally between transistors X22 and X24. Capacitor C23 is connected across the supply to provide a low output impedance at high frequencies.

## Protective Devices and Other Facilities

### High Temperature Cut-Out

28. The contacts of a thermal cut-out TC1 are wired in the positive line (common rail) of the -40 volts supply to protect the power transistors from damage by overheating. Once triggered, the cut-out must be manual-

ly reset after the cause of the overheating has been found and remedied.

### Delayed Power Supply Switching

29. The application of the -40 volts supply to the transistor amplifiers and servo motor drive circuit is automatically delayed by some 30 seconds so that these stages are inoperative until the valve heater (V1) in the D. C. Impedance Converter Stage has had time to warm-up. The thermal delay switch TD1/1 is heated from the -40 volts supply, and its contact is employed to energise the power switching relay RL2/2 on the termination of the delay period. Contact RL2. 1 will thereon close to apply the -40 volts supply to the transistor amplifiers and servo motor drive circuit, and contact RL2. 2 will change-over to reset the thermal delay switch and hold-in relay RL2/2. It will be noted that TD1/1 is not subject to control by the thermal cut-out TC1.

### Cooling Fan

30. The transistor heat-sink cooling fan is driven by a small permanent magnet motor M 1 energised by the -40 volts supply. The armature current is limited by series resistor R57. Capacitor C16, connected directly across the motor terminals, reduces high frequency radiation caused by motor brush noise. The supply to the motor is not subject to control by the thermal cut-out TC1. Air intake is via a wire-mesh covered aperture cut into the panel of the unit.

### Operational Facilities

### Motor Drive Cut-Off

31. A panel-mounted MOTOR DRIVE switch SW1 is provided to enable the amplifier and motor drive circuits to be cut-off if it is desired to hold the servo ready for immediate use but not actually in operation. This facility could be employed when the servo is to be driven from an amplifier which may have an output in excess of 100 volts during the warm-up period. The contacts of the MOTOR DRIVE switch are wired in the supply line to the power switching relay RL2/2, so that the relay will drop-out when SW1 is set to OFF. Relay contact RL2. 1 will then open to remove the motor drive, and contact RL2. 2 will change-back to energise the heating element of the thermal-delay switch TD1/1. On the termination of the 30 seconds delay period imposed by TD1/1, contact TD1. 1 will close to permit the power switching relay RL2/2 to be energised via SW1 when that switch is closed to re-apply motor drive.

### Overload Circuit

32. The overload circuit gives warning when large errors exist in the servo system, which condition is generally caused by demanding too great an accelleration from the servo motor. The circuit consists of a transistor amplifier X15 connected between the -40 volts and zero volts line, so as to form a variable resistance shunt across the filament of a low consumption 6 volts indicator lamp LP1. Under normal circumstances the base potential of transistor X15 is held at a sufficiently negative potential with respect to the emitter so that X15 passes a heavy current and shorts out the indicator lamp. In the overload condition, the power and/or paraphase amplifier stages will saturate with the result that the potential at the junction of resistors R22 and R23 will go positive. This change in potential is applied to the base of transistor X15 to reduce the collector current and thus increase the shunt resistance across indicator lamp LP1 which will light to signal an overload. The a. c. component of the amplified

TABLE 4

PROGRAMME CARD CONNECTOR PIN ASSIGNMENTS

| SK1 PIN NO. | CONNECTION |
|---|---|
| A | Slave C - high |
| B | Slave C - tap 2 |
| C | Slave C - tap 4 |
| D | Slave C - tap 5 |
| E | No connection |
| F | Slave C - tap 7 |
| H | Slave C - tap 8 (centre) |
| J | Slave C - tap 10 |
| K | Slave C - tap 11 |
| L | Slave C - tap 13 |
| M | Slave C - tap 14 |
| N | Slave C - low |
| P | No connection |
| R | +100V reference supply |
| S | -100V reference supply |

signal is routed to the computer central overload circuit via capacitor C19. The germanium diode MR3 serves to prevent low level noise voltages reaching the central overload circuit and signalling a spurious overload condition.

### Programme Card

33. The Servo Multiplier Type TJ725 is fitted with one linear potentiometer, slave C, tapped at eight points in addition to the centre tap, to permit the potentiometer to be used as a generator of discontinuous functions by the connection of resistive padding networks. A plug-in printed circuit programme card is provided to carry the padding resistors, so that once a function has been set-up, the card can be stored ready for future use. The programme card is fitted with 15 in-line taper pin connections which engage with a matching socket SK1 mounted in the base of the multiplier chassis. Access to the socket is by way of a rectangular aperture let into the top dust-cover of the unit. The supply and potentiometer tapping connections to the programme card socket SK1 are listed in Table 4.

# SECTION 6

## INITIAL SETTING-UP PROCEDURE

### General

34. The instructions detailed in this Section are given to enable the operator to restore the unit to correct working order after repairs have been carried out. The complete procedure will normally only be required after the unit has been subjected to an extensive repair necessitating the disconnection and removal of sub-assemblies. Directions for the breakdown and re-assembly of the unit are given in Section 8 of this handbook.

### Test Equipment Required

35. The following items of test equipment will be required.

(1) Low frequency oscillator capable of providing sinusoidal and square wave signals over the frequency range 0.1c/s to 1kc/s.

(2) Oscilloscope.

(3) Mains variac rated for 100VA.

(4) Avometer Model 8.

Additionally, a ±100 volts stable reference supply will be required. Solartron Supply Sub-unit AS756 is a suitable source.

### Setting-up Procedure

36. (1) Connect mains input from variac at plug PL1, pin A being line, pin B neutral and pin C earth.

(2) Connect DIRECT pins on link panel LK1.

(3) Check that the mains supply stands at 230V.

(4) Check that voltage selector panel is set for a 230V input.

(5) Insert a fuse rated for one ampere in FS1 carrier.

(6) Using the Avometer, check that the resistance between the OV rail and chassis is greater than 100,000 ohms.

(7) Check that valve V1 is firm in its base, and of correct type (12AC6).

(8) Disconnect resistors R36 and R37 from the OV rail.

(9) Set MOTOR DRIVE switch to OFF.

(10) Connect a load resistor, value 100 ohms rating 50 watts, across the unswitched -40V rail and the OV rail.

(11) Set variac to give zero volts output.

(12) Close external circuit breaker to apply mains input to variac, and advance variac to give an output of some 3-4 volts to the servo unit under test.

(13) Confirm polarity of -40V and +12V rails.

(14) Advance variac to give an output of 230V.

(15) Adjust potentiometer RV6 to set the potential of the +12 volts rail to +12V.

Note
Early models cannot be set to less than +12.8V.

(16) Check that the heater of valve V1 is lit.

(17) Check that the voltage of the -40V rail lies between -39V and -41V.

(18) Check with oscilloscope that both the -40V and +12V rails are free from oscillation or excessive hum.

(19) Check that fan blades are rotating in a clockwise direction as viewed from the front of the unit.

(20) Open external circuit breaker to remove mains input from unit.

(21) Connect the 100 ohms load resistor across the switched -40V rail and OV rail.

(22) Close external circuit breaker, and set MOTOR DRIVE switch to on.

(23) Check that the potential of the unswitched -40V rail does not exceed -50V.

(24) Check that the thermal delay switch TD1/1 operates some 30 seconds after the external circuit breaker is closed.

(25) If necessary, set time delay to 30 seconds by adjustment of the set screw on TD1/1.

(26) Check that the collector voltage of X1 is approximately -12V, and that the collector voltage of X4 is approximately -20V.

(27) Earth the grid (pin 1) of valve V1.

(28) Check that the links A, B, C and E are connected.

(29) Confirm that the -40 supply is connected to R76, R24, R21 and the collector of X16.

(30) Check with the oscilloscope that no oscillation is present at the emitter of X16.

(31) Confirm that the -40V supply is connected to R50, R52 and the collector of X21.

(32) Check with the oscilloscope that no oscillation is present at the emitter of X21.

(33) Confirm that the -40V supply is connected to R31 and R34.

(34) Confirm that the -40V supply is connected to R39 and R40.

(35) Open external circuit breaker to remove mains input.

(36) Solder resistors R36 and R37 in place.

(37) Remove 100 ohms load resistor from the -40V supply.

(38) Connect a load resistor value 50 ohms rating 20 watts, across the servo motor (M2) leads in place of the motor.

(39) Close external circuit breaker to apply input to the unit.

(40) Check that after a period of five minutes the outputs at the emitters of X16 and X21 are steady at -21V, and that the voltages on R29 and R43 are -3V.

(41) Vary the mains input voltage between 214V and 246V, checking that both the -40V and +12V rails are free from oscillation, and that the hum level on each is less than 200mV and 80mV respectively.

(42) Set the MOTOR DRIVE switch to OFF, and check that the OVERLOAD indicator lamp lights and is extinguished after some 30 seconds when the thermal delay switch operates. Set MOTOR DRIVE switch to on.

(43) Apply a 10c/s, 1V, r.m.s. sinusoidal input to the control grid (pin 1) of V1, and with the oscilloscope check that both outputs swing through 28V peak-to-peak, and that no oscillation is present at any time of the cycle.

(44) Reduce the amplitude of the sinusoidal input until the output falls to 6V peak-to peak. Check that the r.m.s. value of the input necessary to give that output is between 20 and 40mV.

(45) Apply a 300c/s, 1V r.m.s. sinusoidal

input to the control grid (pin 1) of V 1, and with the oscilloscope, check that neither output lags the input.

(46) Apply a 1kc/s, 0.2V r.m.s. sinusoidal input at pin 18 on plug PL3 and again check outputs for lags.

(47) Open external circuit breaker to remove mains input from unit, and set MOTOR DRIVE switch to OFF.

(48) Check that the resistances between all potentiometer wipers to signal ground and to chassis is greater than one megohm.

(49) Disconnect the 50 ohms load resistance from the servo motor leads, and re-connect the leads to the motor.

(50) Apply the ±100V reference potentials to the unit at plug PL2, thus:-

| | |
|---|---|
| -100V | Pin 1 |
| +100V | Pin 2 |
| Signal ground | Pin 3 |

(51) Close external circuit breaker to apply mains to unit, and set MOTOR DRIVE switch to ON.

(52) Check that after the 30 seconds delay imposed by TD1/1, the servo pointer moves off and finally comes to rest at zero indicating that the servo motor is correctly wired in circuit.

(53) Should the servo pointer oscillate, set MOTOR DRIVE switch to OFF, and reverse motor connections.

(54) Close MOTOR DRIVE switch and check that the servo is now stable.

(55) Should the pointer still oscillate, ensure that the ±100V reference supplies are getting to the feedback potentiometer. Check continuity of arm fuse FS3.

(56) With servo in operation, set the control grid of valve V1 to OV by adjustment of RV1.

(57) Set MOTOR DRIVE switch to OFF, and open external circuit breaker.

(58) Remove motor/potentiometer assembly and replace in such a position as to enable the pointer to be adjusted, i.e. with the dial facing outwards.

(59) Close external circuit breaker, and set MOTOR SWITCH to ON.

(60) Using the special tool provided, set pointer to zero.

(61) Open external circuit breaker and set MOTOR SWITCH to OFF.

(62) Refit motor/potentiometer assembly in operational position.

(63) Apply a d.c. potential across one of the linear slave potentiometers, and monitor the output from the arm of this potentiometer on the oscilloscope.

(64) Apply a 100V peak-to-peak, 1c/s, square wave signal to the servo input (pin 18 on plug PL3).

(65) By adjustment of potentiometer RV8 set the positive transient to approximately 5%.

(66) By adjustment of potentiometer RV2 set the negative transient to approximately 5%.

SECTION 7

## FAULT FINDING

37. The following procedure is given to assist in locating any electrical fault which the unit may develop. Directions for dismantling the equipment for repair purposes are given in Section 8 of this manual, and a list of quiescent test voltages is given in Table 5.

(1) Switch off supplies and disconnect all leads from the servo unit

(2) Disconnect leads from servo motor M2, and connect a 50 ohms, 20 watts resistive load in place of the motor.

(3) Connect mains input at plug PL1, and earth control grid of V1. Connect DIRECT pins on link panel LK1.

(4) Apply mains voltage to unit and set MOTOR DRIVE switch to ON.

(5) Check that the thermal delay switch operates within 30 -,60 seconds of applying the mains input.

(6) Check that the potential of the +12 volts rail is in fact +12V, and that no excessive hum or oscillation is present.

(7) Check that the potential of the -40 volts rail is between -39V and -40V, and that no excessive hum or oscillation is present.

(8) Check that the collector voltage of transistor X1 is approximately -12V.

(9) Check that the collector voltage of transistor X4 is approximately -20V.

(10) Check that the emitter voltage of transistor X16 is -21V. If necessary set to this value by adjustment of RV1. Check for oscillation.

(11) Check that the emitter voltage of transistor X21 is -21V. Check for oscillation.

(12) Check that the emitter voltage of transistor X18 is -3V. Check for oscillation.

(13) Check that the emitter voltage of transistor X20 is -3V. Check for oscillation.

(14) Disconnect control grid of V1 from earth.

(15) Apply a low frequency signal to input of unit, and check that the voltage at both terminals of the load resistance can swing ±14V from the steady value of -21V.

(16) Apply a 300c/s, 1V r.m.s. signal to servo input and check that neither output lags on input.

(17) Apply a 1kc/s, 1V r.m.s. signal to servo input, and with RV8 set in a suitable position, check that both outputs lead on input.

(18) Switch off mains input and set MOTOR DRIVE switch to OFF.

(19) Disconnect load resistance and reconnect servo motor M2.

(20) Apply reference voltages to plug PL2, thus:-

| | |
|---|---|
| Pin 1 | -100V |
| Pin 2 | +100V |
| Pin 3 | Signal ground |

(21) Apply mains input and set MOTOR DRIVE switch to ON.

(22) Check control grid voltage of V1 with Avometer, and if necessary bring to zero by adjustment of RV1.

(23) The servo unit should now be in working order.

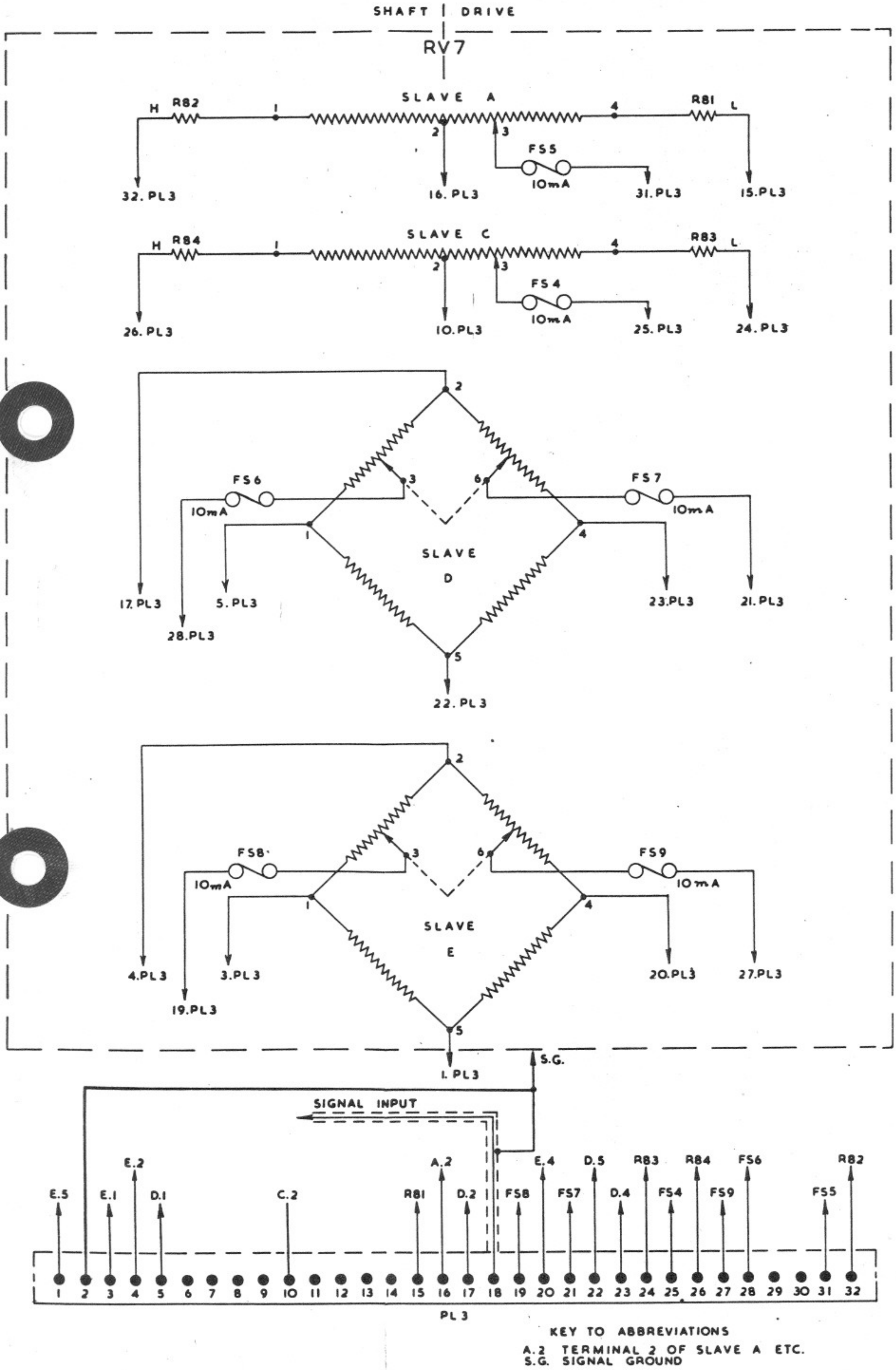


Fig. 10 Circuit Diagram, Potentiometer Assembly TJ961

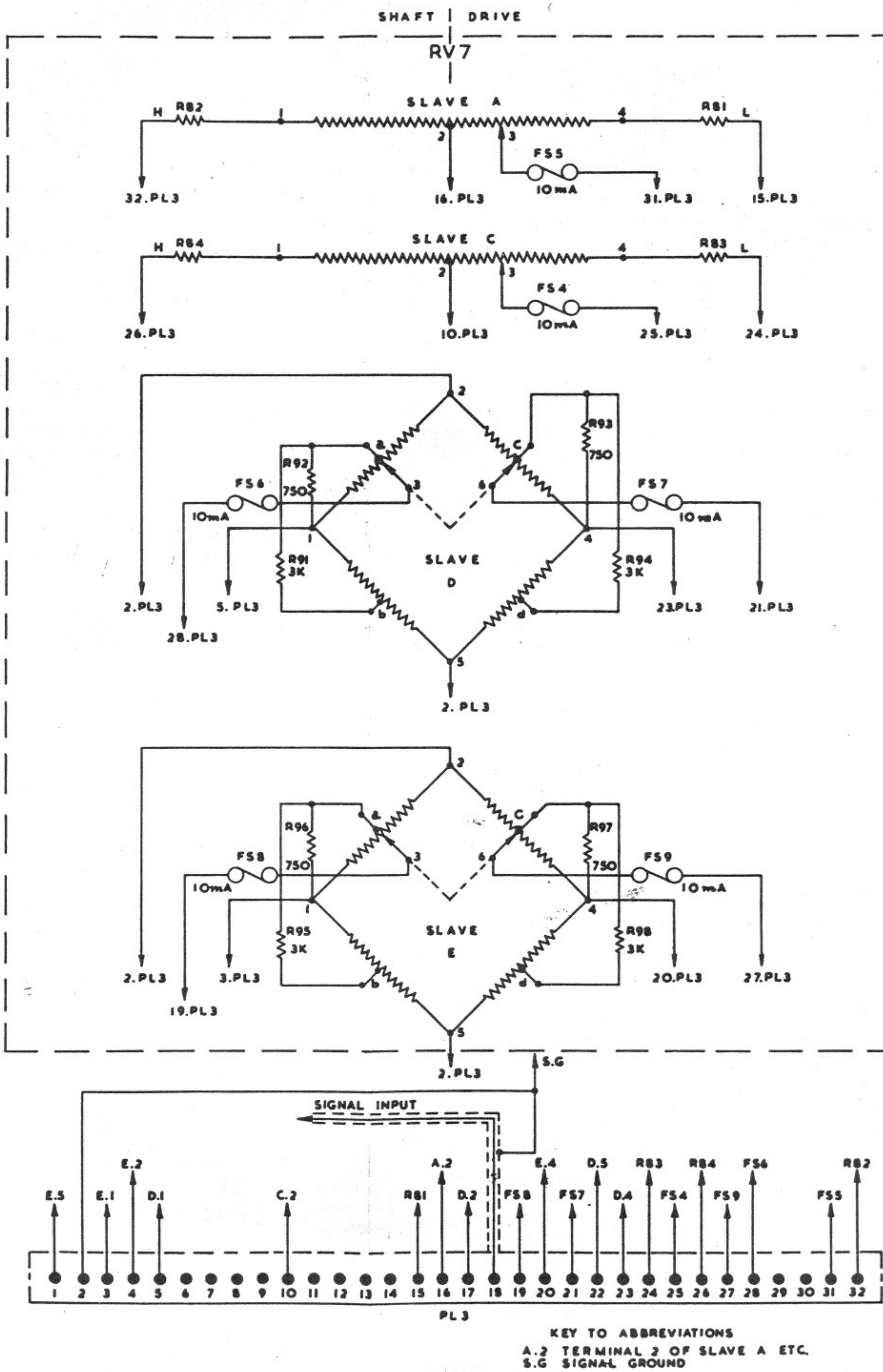


Fig. 11 Circuit Diagram, Potentiometer Assembly TJ961 (modified)