SECTION 4

THEORY OF OPERATION

4.1 GENERAL

The Model 9975 Thermometer Bridge is a resistance ratio bridge based on the principle of the Direct Current Comparator as developed by N. L. Kusters and other members of the staff of the National Research Council of Canada and manufactured under licence by Guildline Instruments.

4.2 DIRECT CURRENT COMPARATOR

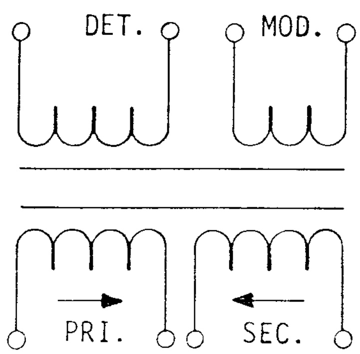


Fig. 1a Current Comparator

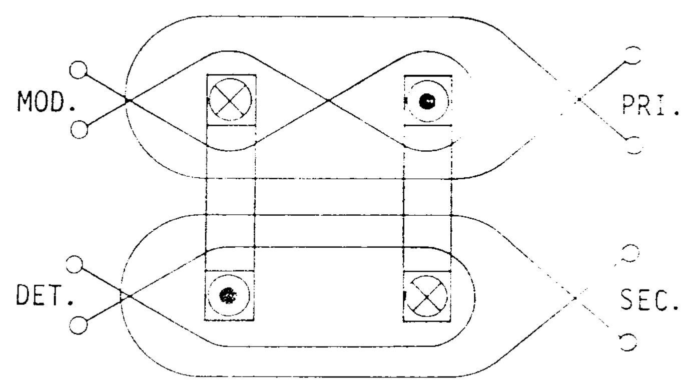


Fig. 1b Windings on Cores

The Direct Current Comparator is a multiple winding toroidal transformer device (Fig. 1a) in which the primary and secondary windings carry direct currents and in which modulator and detector windings are used for the detection of dc flux in the core. When the primary and secondary ampere-turns are equal and opposite there is zero resultant dc flux in the core. This balance condition can be detected by modulation of the core permeability using the principle of the second harmonic modulator (Fig. 1b). The amplitude of the double frequency positive and negative voltage peaks induced in the detection windings are compared by a peak detector. The dc output of the detector is proportional to their difference. The presence of dc flux in the cores due to primary-secondary ampere-turns unbalance is indicated by the detector output both in magnitude and polarity.

4.3 DIRECT CURRENT COMPARATOR BRIDGE

Conventional methods of comparison of four-terminal resistors involve a comparison of voltage drops when the same current passes through both resistors. The ratio of resistance is obtained from the ratio of voltages. This applies in a potentiometric comparison of resistors or in a conventional bridge configuration such as the Kelvin bridge.

In the potentiometric method, at balance no current flows in the measuring leads and lead resistance is therefore unimportant. Resolution and accuracy are limited by (and cannot be better than) the stability of the currents in the tested resistors and in the potentiometer.

On the other hand, the Kelvin bridge method is sensitive to the resistance of measuring leads but current stability is unimportant. Both potentiometric and Kelvin bridge methods suffer from the disadvantage that when scaling resistors in decade steps the same current must be passed through both resistors and the greatest power is dissipated in the largest resistance.

The D.C.C. Bridge is not sensitive to measuring lead resistance, it does not require current stability and when scaling resistors the greatest power is dissipated in the smallest resistance.

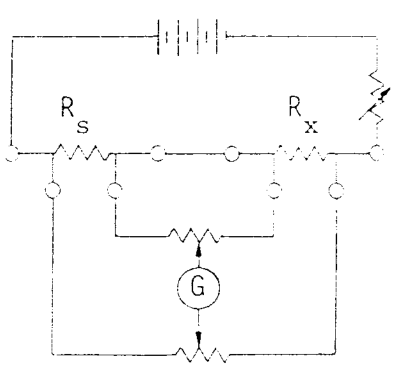


Fig. 2a Kelvin Bridge

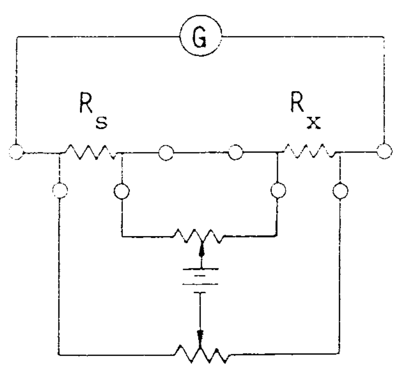


Fig. 2b Conjugate Kelvin Bridge

In the conventional Kelvin bridge (Fig. 2a) the same current is passed through both resistors and the resulting voltage drops are in the same ratio as the resistance values. The resistance ratio is obtained from the voltage ratio.

In the conjugate Kelvin bridge (Fig. 2b) which is obtained by interchanging the positions of the current source and the detector, different currents flow in the two resistors to produce equal and opposite voltage drops. The ratio of resistors can now be obtained from the ratio of currents if a suitable device is available for measurement of the current ratio. The Direct Current Comparator is such a device.

4.4 BASIC OPERATION

The two resistors to be compared are supplied from different current sources (Fig. 3) and the ratio of the two currents is measured when the voltage drops across the two resistors are equal and opposite. One or both of the direct current sources can be adjusted until the voltage across the resistors are equal. This balance condition is indicated by the galvanometer G. The current comparator is then used to obtain an ampere-turn balance between the primary and secondary windings by adjustment of the variable turns N_x until zero dc flux exists in the core. This zero core condition is sensed by the detector D.

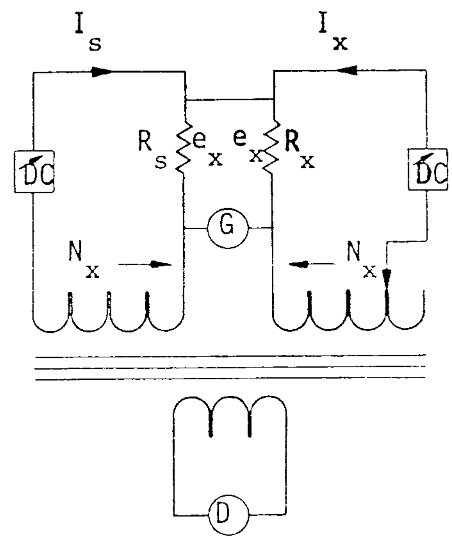


Fig. 3 D.C. Comparator Bridge Basic Operation

When G = 0,

$$e_s = e_x$$

$$I_s R_s = I_x R_x$$

$$\frac{R_x}{R_s} = \frac{I_s}{I_x} \qquad (1)$$

When detector D indicates zero dc flux in the core:

$$I_s N_s = I_x N_x$$

$$\frac{I_s}{I_x} = \frac{N_x}{N_s} \qquad (2)$$

From (1) and (2)

$$\frac{R_x}{R_s} = \frac{I_s}{I_x} = \frac{N_x}{N_s}$$

and

$$R_x = \frac{N_x}{N_s} R_s \qquad (3)$$

This simple bridge would have the disadvantage of requiring simultaneous manual balances for both voltage and ampere-turns. In such an arrangement highly stable current supplies would be essential.

In a practical form of the bridge (Fig. 4) the requirement for two simultaneous balances and the need for highly stable supplies are eliminated by making the ampere-turn balance automatic. The output from the detector winding is used to control the current in the secondary winding so that the zero flux condition in the core, i.e. an ampere-turn balance, is maintained. The only manual balancing operation now required is adjustment of the primary turns dial until the primary and secondary currents produce equal voltages across the compared resistors as indicated by the galvanometer G.

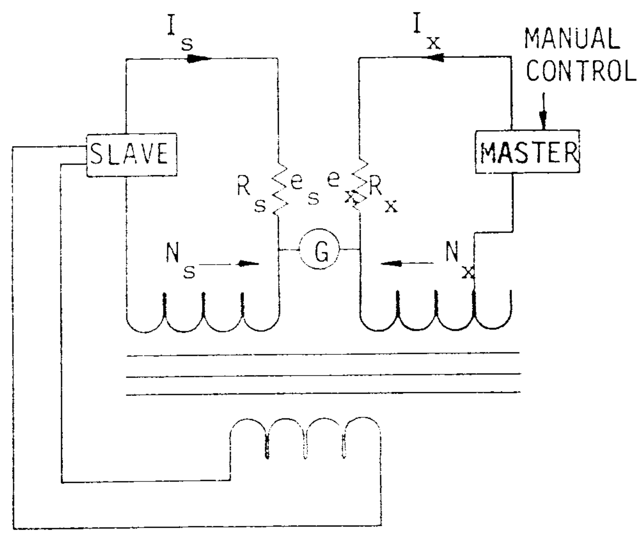
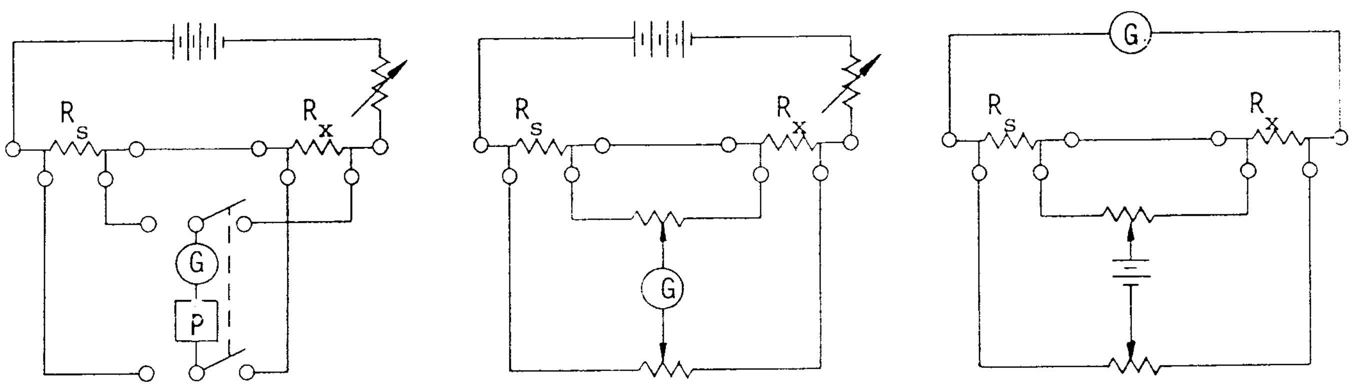


Fig. 4 D.C. Comparator Bridge
Automatic Ampere-Turn Balance

At balance, no current flows in the potential leads and the Direct Current Comparator Bridge thus possesses the principal advantage of the potentiometric system but, at the same time, because of the automatic ampere-turn balance, there is no necessity for current stability. In addition to having the advantages of both the potentiometric and bridge methods, the Direct Current Comparator Bridge adds a unique advantage in that the ratio of power dissipation in the compared resistors is the inverse of the ratio of resistance.

4.5 POWER DISSIPATION IN THE COMPARED RESISTORS



Potentiometer Method

Kelvin Bridge

Conjugate Kelvin Bridge

Fig. 5

In the potentiometric and Kelvin bridge methods of comparison of resistors the same current flows through both. (Fig. 5).

$$P_s = I^2R_s \quad \text{and} \quad P_x = I^2R_x$$

The ratio of power is:

$$\frac{P_s}{P_x} = \frac{I^2R_s}{I^2R_x} = \frac{R_s}{R_x} \qquad (4)$$

The greatest power is dissipated in the largest resistance.

In the Direct Current Comparator Bridge different currents flow in the two resistors to produce the same voltage across each:

$$P_s = \frac{E_s^2}{R_s} \text{ and } P_x = \frac{E_x^2}{R_x}$$

$$\frac{P_s}{P_x} = \frac{R_x}{R_s} \qquad (5)$$

The greatest power is now dissipated in the smallest resistance.

The Model 9975 Resistance Bridge is a 10:1 ratio bridge with a fixed 1000 turns on the standard (R_s) side and the 10,000 turns variable on eight decades on the measured (R_x) side.

$$\frac{R_x}{R_s} = \frac{N_x}{N_s} = \frac{10}{1} = \frac{P_s}{P_x}$$

The smallest power is dissipated in the measured resistor or thermometer.

4.6 THE THERMOMETER BRIDGE

Figure 4-1 shows a simplified schematic diagram of the bridge circuit in the $R_s \leq 1$ kΩ mode. Current from the reversible constant current supply flows in the variable turns N_x and through the thermometer or measured resistor R_x. A second current flows in the fixed number of turns N_s and in the reference resistor R_s.

For the bridge to be in balance, both the net ampere-turns imposed on the comparator cores (indicated on an ampere-turn balance meter (ATB)) and the difference between the voltages across the thermometer element and the reference resistor (as measured by a galvanometer (G) must not change as both currents are reversed.

Single balance operation is achieved by making the ampere-turn balance automatic as described above and be proportionate summing of the residual ampere-turn balance signal and the output of the photocell galvanometer amplifier.

Automatic balance of the net ampere-turns is achieved by means of an open-loop control, which gives coarse balance. The open-loop control is provided by an ampere-turn tracking signal generator, whose output is proportional to the ampere-turns on the thermometer side of the bridge. This circuit causes a current to flow in the reference side to keep the net ampere-turns at approximately zero. The closed-loop control, from the magnetic modulator and peak detector, tends to keep the net ampere-turn unbalance at zero.

To permit the residual unbalance signals to be summed, the galvanometer photocell amplifier output and the residual output from the ampere-turn balance detector are connected to the input of a summing amplifier. Feedback from the photocells to the galvanometer is obtained by magnetic coupling in the comparator through the 10 turn winding. If the galvanometer is deflected current flows in the 10 turn winding to impose ampere-turns on the comparator proportional to the galvanometer deflection. The automatic ampere-turn balance circuit then causes a compensating current to flow in winding N_s and resistor R_s. Ampere-turn and voltage balance are restored and R_s acts as the feedback resistor of the galvanometer.

Galvanometer offset may occur due to (a) a change in the variable number of turns (N_x) on the comparator or (b) due to a thermal emf in the potential leads of the thermometer and standard resistor or a mechanical offset of the galvanometer.

(a) Dial Setting Changed (Bridge unbalanced)

If under constant current conditions in the R_x loop the N_x turns are increased, a signal generated by the ampere-turn balance detector is applied to the slave power supply to increase the current in N_s. Ampere-turn balance is restored to within close limits but any residual signal still produced by the ATB detector, which may be too small to deflect the ATB meter, is fed to the summing amplifier as an out-of-balance signal.

Thus the current in R_s is increased when the current in R_x is unchanged and the galvanometer G is deflected. The resulting signal from the galvanometer amplifier is fed through a resistor to the 10 turn winding in polarity such as to take over the extra current demand on the N_s turns. Ampere-turn balance is maintained and the current in N_s and R_s is reduced to tend to restore the galvanometer deflection to zero. This is similar to the usual feedback action in a conventional photocell galvanometer amplifier but in this case it is obtained through magnetic coupling. The signal from the output of the photocell amplifier is also taken to the summing amplifier which deflects detector D_1 by an amount proportional to the sum of the out-of-balance signals in the voltage circuit plus any residual unbalance signal from the ampere-turn balance detector.

On current reversal this deflection of D changes polarity. To reduce it to zero the dial setting N_x must be adjusted until the sum of the signals from both ATB detector and galvanometer amplifier is reduced to a level at which no change in D_1 deflection occurs on current reversal.

(b) Thermal EMF or Mechanical Offset of Galvanometer G

A thermal emf in one of the potential leads between the compared resistors (the only location of a thermal emf which is of any significance) does not reverse when the currents are reversed but does cause a galvanometer signal to be generated. As described in the previous section bridge unbalance (due to offset of N_x dials) caused a reversing signal at detector D_1. The corresponding D deflection due to a thermal emf or mechanical offset of the galvanometer is of unchanging polarity and shows as a constant deflection proportional to the magnitude of the disturbance.

A similar deflection is also produced by photocell amplifier zero drift and hence the signal at this point in the circuit is unsuitable for chart recorder drive. The effect of galvanometer zero drift and thermal emf's can be removed to leave only the bridge unbalance signal by use of the detector-demodulator.

4.7 DETECTOR-DEMODULATOR

The bridge currents can be reversed either manually or automatically. In the manual mode, the operator reverses the current from the current supply and adjusts the number of turns N_x until the indication on the meter D_1 is the same for both directions of current flow. The dial reading that shows the number of turns of the winding also indicates the ratio R_x/R_s.

In the automatic mode, the currents are reversed (modulated) periodically. The turns may be adjusted, as in the manual mode, until the deflection of D_1 is the same for both directions of current flow. However, in the automatic mode, the detector-demodulator may be switched in, to compare the signals appearing at meter D_1 for the forward and reverse directions of current and generate at D_2 and on the recorder a signal proportional to their difference. Thus, the out-of-balance condition of the bridge can be read either as the difference of two readings at D_1 or as a steady-state deflection at D_2. An external chart recorder can be connected at D_2.

The meter engraved "GALVANOMETER" performs the functions of both D_1 and D_2 according to the positions of the "GALVANOMETER" switch and the "MAN/AUTO" switch.

Galvanometer Switch Position	Man/Auto Switch Position	Galvanometer Meter Position	Recorder
D_2	Manual	Inoperative	Inoperative
D_1	Manual	D_1	Inoperative
D_1	Auto	D_1	Operative
D_2	Auto	D_2	Operative

The method of operation of the detector-demodulator is as follows. While the current is flowing in the forward direction, switch F is closed after switching transients have disappeared and the signal at D_1 is stored in a capacitor. Switch F is then opened, the current is reversed, and, after the transients have decayed, switch R is closed and the signal at D_1 is stored on a second capacitor. The difference between the voltages on the two capacitors is the recorder output at D . Thermal voltages in the potential circuit of the thermometer or reference resistor produce a common-mode signal on the two capacitors that is ignored by the difference amplifier. Similarly, thermal voltages or zero offset or zero drift in the galvanometer are not seen by D or by the external recorder. A continuous record is thereby obtained of the deviation from the set point on the bridge. For noise-suppression purposes the bandwidth of the detector-demodulator can be changed by adjustment of the RC time constant at its input.

The reversing cycle of the bridge should be as short as possible in order to be able to cope with changing thermal emf's. The galvanometer must reach a steady-state deflection during each half-cycle; therefore, it must be fast acting. This is achieved by making the feedback-loop gain high. This provides the additional advantage that the effective dc input resistance of the galvanometer is high enough to make the galvanometer sensitivity constant over the whole range of the bridge.

4.8 NOISE LEVEL LIMITATION

a) Voltage Noise

Voltage noise limits the resolution at 1 nanovolt. It is expressed in proportional parts of the voltage across the resistors:

$$\text{Voltage noise limit} = \frac{10^{-9}\ \text{V}}{I_s R_s}$$

where I_s is the current through the standard resistor R_s.

e.g.

if $R_s = 10\ \Omega$ and $I_s = 10$ mA, then:

$$\text{Voltage noise limit} = \frac{10^{-9}\ \text{V}}{10^{-2} \times 10} = 10^{-8} \text{ or } 0.01 \text{ ppm}$$

b) Current Noise

Current noise limits the resolution at 0.3 micro ampere-turns. It is expressed in porportional parts of ampere-turns in the comparator.

$$\text{Current noise limit} = \frac{0.3 \times 10^{-6}\ \text{AT}}{I_s \times 1000\ \text{turns}}$$

where I_s is the current through the standard resistor and AT are the ampere-turns.

e.g.

if $I = 10$ mA, then:

$$\text{Current noise limit} = \frac{0.3 \times 10^{-6}\ \text{AT}}{10^{-2} \times 10^{3}\ \text{turns}} = \frac{3 \times 10^{-7}}{10} =$$

3×10^{-8} or 0.03 ppm

4.9 GALVANOMETER CIRCUIT

Loop gain in the galvanometer circuit is kept to a minimum of about 500 by setting the $R_s\Omega$ switch according to the resistance value in use. At this gain the response is fast enough to stabilize the galvanometer deflection within 0.5 s. The gain is also at the highest practical value that will not cause circuit instability.

4.10 GALVANOMETER ZERO ADJUST

The galvanometer zero (D_1 only but not D_2 or recorder) is adjusted by the "GALV BALANCE" control (Fig. 4-1). This adjusts the dc current through a 10 turn winding on the comparator. Since the ampere-turns on the comparator are kept in balance automatically this causes a current to flow through N_s and R_s thus, generating the direct voltage to shift the galvanometer zero as required. This comparator current and galvanometer voltage does not reverse on reversal of the measuring currents.

4.11 TRANSIENT SUPPRESSION

A transient suppressor for the galvanometer is also provided by means of current flowing through the same 10 turns. At current reversals of the power supply a transient current flows through the interwinding capacitance of the variable-turn winding and through the resistor R_x, generating an undesirable transient deflection of the galvanometer. The current in R_x also flows through the resistor "r" and generates a voltage that is amplified in the FET and succeeding amplifiers; this is applied to the galvanometer transient-suppressor circuit. The circuit is adjusted to reduce the reversing transient deflection on D_1 to a minimum.

4.12 TIMING CIRCUIT (Automatic Reversal)

In the automatic mode of operation, current reversal is controlled by a timing circuit that is a free-running multivibrator with a normal period of four seconds per cycle. It triggers two monostable circuits that act to close each switch of the detector-demodulator alternately for one second. The turning off of each switch driver, delayed by a few milliseconds, triggers the reversal of the constant-current supply. In this way the switches are closed after the current has been reversed for one second and then are opened a few milliseconds before the currents reverse again. This timing sequence is shown in Fig. 6. The delay of one second between the current reversals and the closure of the detector-demodulator switches is sufficient for any galvanometer switching transients to decay sufficiently to not affect the readings, and the bridge is balanced under steady-state conditions.

Some resistance thermometers at high temperature, and some standard resistors in the range 1 kΩ - 10 kΩ, exhibit dielectric abosrption. The apparent resistance of these elements does not stablize for a number of seconds after current reversal. For this reason, reversal rates of 8 and 16 seconds per cycle for the timing circuit are included. At the slower rates, only the dead time is increased, and the detector-demodulator switches still close for one second just before current reversal.

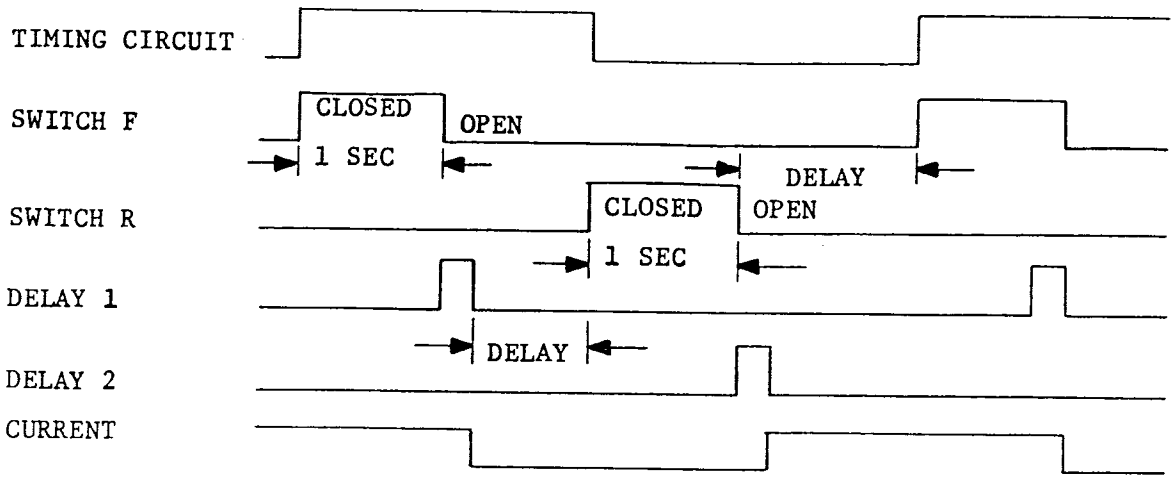


Fig. 6

Sequence of operations with automatic reversal

4.13 NOISE SUPPRESSION

The random noise of both the galvanometer and the current comparator are present in the signal at meter D_1. The band width of the detector-demodulator, and hence the fraction of the noise that passes through to D_2, can be changed by adjustment of the RC time constant at the input of the detector-demodulator to 0.3 s, 1 s, or 3 s. Each FET switch is closed for one second per cycle; for time constant t = 0.3 s, a signal reaches final value within one cycle and no advantage is gained by making the time constant shorter. With t = 3 s, about 10 cycles are required for an input signal to reach final value at the output. The meter D_1 can always be used to balance the bridge quickly, since it is not affected by the time constant of the detector-demodulator. The same number of cycles are required, with a given time constant, for a signal to reach final value at the output irrespective of the reversal rate. A slower reversal rate is accompanied by a longer response time without a corresponding reduction of the noise band width. The reversal rate should be as fast as possible to suppress the effect of changing thermal emf's on the measurement.

4.14 AMPERE-TURN TRACKING CIRCUIT

A voltage proportional to the current through R_x is generated across the resistor "r" and is amplified in the AT tracking signal generator circuit with a gain proportional to the number of turns N_x. Thus, a tracking signal that is proportional to the ampere-turns in the thermometer side of the comparator is applied to the amplifier that supplies current to N_s and R_s. A small adjustment of the amplitude of the AT tracking signal is provided by the "HIGH TRACK" control which should be set so that the ATB detector does not deflect on current reversal. After adjustment for no change in deflection of ATB on current reversal the meter deflection may be centered with the COMP BAL control. When the bridge range is changed by changing the value of R_s, the tracking signal level at the resistor "r" is also adjusted.

The voltage across the resistor "r" causes a current to flow into the input impedance of the first amplifier of the AT tracking signal generator and back through the link joining the lower potential terminals of R_s and R_x formed by one potential lead from each resistor. This current reverses with the current through R_x and could cause an error in the galvanometer balance. The maximum voltage on "r" is 1 V; the input impedance of the FET amplifier is 10^{11} Ω, so a link impedance of 100 Ω may generate an error voltage of 1 nV. If the link impedance is below 10 Ω, this error can be ignored as it is below the noise level of the bridge.

4.15 THERMOMETER CURRENT LEVELS

The current through the thermometer is set by the CURRENT I mA control. The steps available are 0, 0.001, 0.003, 0.01, 0.03, 0.1, 0.3, 1, 3, 10, 30 and 100 mA. This permits a test made at a given current to be repeated easily at the same current.

4.16 THERMOMETER SELF-HEATING DETERMINATION

In addition to the current ranges given above, any current can be increased by $x\sqrt{2}$, thereby increasing the self-heating effect of the thermometer element by x2. At the same time, the sensitivity of the detector summing amplifier is reduced by $x\sqrt{2}$ so that if there is no change in the thermometer resistance when the current is increased, there will be no change in the meter indication. A change in the meter indication is equal to the self-heating error at the operating current. The self-heating effect can be measured even if the temperature is not constant. The deflection on the recorder chart record, when the current is multiplied by $\sqrt{2}$ and then is returned to normal, is easily identified even if the normal recorder trace is not steady.

4.17 WIRING TO SIDE-PANEL TERMINALS

Twin conductor shielded leads. (Guildline SCW or equivalent) should be used to connect R_x and R_s to the bridge so that long leads may be used without interference. The potential leads and the current leads should be separately shielded and all shields connected together and to the terminal CCT COM.

4.18 BRIDGE OUTPUT

The signal from the galvanometer amplifier to the summing circuit is obtained from the point where the feedback signal is supplied through a 10 kΩ resistor to 10 turns on the comparator. Thus, the sensitivity is constant at 1 mV/μA.turns. This is independent of the feedback-loop gain of the galvanometer circuit, provided that the loop gain is sufficiently high. The output of the ampere-turn detector is adjusted to be 1 mV/μA.turns also so that these two signals may be added with equal weight in the summing circuit. The gain of the summing amplifier may be set at the GALVANOMETER SENSITIVITY control at values from x1 to x1000. The output at meter D_1, and also at meter D_2, is from 1 V/10 μAT to 1 V/10 mA.turns, since the detector-demodulator gain is unity. The range is equivalent to 1 V/m C^{o} to 1 V/^{o}C when using a 25 Ω thermometer with a current of 1 mA.

The output from the "RECORDER" terminals is suitable for driving a 1 mA 1000 Ω deflectional type chart recorder or a potentiometric type as available. (The slower response of the deflectional type gives a cleaner (noise-free) trace).

4.19 PROGRAMMED PLUG $R_s \leq 1$ kΩ, $R_s \geq 10$ kΩ

A programmed plug is supplied on the side-panel which determines the range of the bridge. When this plug is inserted with the marking $R_s \leq 1$ kΩ facing up, the circuit configuration is as shown in Fig. 4-1. When the plug is inserted with the marking $R_s \geq 10$ kΩ facing up, the circuit is as shown in Fig. 4-2.

In the configuration as shown in Fig. 4-1, the input resistance to the detector would be too high for resistances of values greater than 1 kΩ 1 kΩ:10 kΩ (R_s:R_x).

To overcome this problem the bridge can be electically inverted by inserting the programmed plug with the marking $R_s \geq 10$ kΩ facing up.

The master current supply and the slave current supply are common at the N_x and N_s windings, with the slave current supply delivering only the error current.

SECTION 5

MAINTENANCE

5.1 INTRODUCTION

This section lists the procedures to completely check-out the bridge and details field adjustments. If these procedures show results outside the prescribed limits contact the Guildline representative for advice and further instructions.

5.2 DIAL LINE-UP

This procedure checks the accuracy of the inter-dial relationship. Use of a chart recorder is recommended so that a permanent record of the relationship is available for future reference.

a) With the instrument switched OFF, link the R_x terminals on the side-panel together with the order C_1 to C_2 to P_2 to P_1.

Connect a 10 Ω standard resistor to the R_s terminals.

Connect a chart recorder to the REC terminals and adjust its mechanical zero to centre the trace.

Set the CURRENT I_x mA switch to 0, the x1 x$\sqrt{2}$ switch to x1.

Set the R_x/R_s dials to 00 000 000.

Set the R_s Ω switch to 10.

Set the MAN/AUTO switch to AUTO.

Set the REV RATE SEC switch to 4.

Set the TIME CONSTANT SEC switch to 0.3.

Set the GALVANOMETER SENSITIVITY switch to x1.

Set the GALVANOMETER D1/D2 switch to D1.

b) Turn the POWER OFF/ON switch to ON and centre the AMPERE TURN BALANCE meter using the COMP BAL control on the side-panel.

c) Turn the CURRENT I_x mA switch to 100 and increase the GALVANOMETER SENSITIVITY switch to x100 in steps, adjusting the GALV BALANCE control as necessary to centre (0) the GALVANOMETER reading. Adjust the TRANSIENT SUPPRESSION control to minimize the reversal kick. (CCW end of control).

d) Turn the GALVANOMETER D1/D2 switch to D2. The GALVANOMETER should be within ±2 minor divisions of zero after allowing for settling time. If not repeat step (c). If still not turn the CURRENT I mA control and the GALVANOMETER controls back to 0 and x1. While still in D2 adjust the REC ZERO control on the side-panel so that the GALVANOMETER indicates 0. (Centre trace on chart recorder). Repeat steps (c) and (d).

e) Set the R_x/R_s dial x10^{-7} to position "1". The deflection of the chart recorder trace should move approximately 1/10 of full scale. If not adjust the REC SENS control on the side-panel. This deflection represents 1 part in 10^8 of full scale of the bridge and will be used for checking the dial line-up in terms of the x10^{-7} dial. Return this dial back to "0" and the CURRENT I_x mA switch back to "0".

CAUTION

BEFORE MAKING ANY CHANGES TO THE MEASURE DIALS
ENSURE THE CURRENT I_x mA CONTROL IS SET BACK TO 0.

f) For ease of description the R_x/R_s dials will be referred to as measure dials 1 through 8, measure dial 1 corresponding to the x1 dial and measure dial 8 to the x10^{-7} dial. Turn measure dials 1 to "0", 2 to "-1" and 3 to "X". This sets the total of measure dials 3 against a negative step of measure dial 2.

g) Turn the CURRENT I_x mA switch to 100 and note the deflection on the chart recorder. The deflection should not exceed 1/4 of that obtained in step (e).

Return the CURRENT I_x mA switch to 0, and measure dial 2 to "0", and measure dial 3 to "-1", measure dial 4 to "X". Repeat step (g).

h) Repeat steps (f) and (g) for the following dial combinations with all other dials set to zero:

DIAL	SET	DIAL	SET
2	-1	3	X
3	-1	4	X
4	-1	5	X
5	-1	6	X
6	-1	7	X
7	-1	8	X

The deflection of the chart recorder should not exceed 1/4 of that obtained in step (e) for any of the above measure dial settings.

i) Because of tracking problems, a "-1" step is not included on the first dial. However, the line-up between the first step of dial 1 and the "X" step of dial 2 can be measured by comparing the ratio of two equal value standard resistors with dial 1 set to "1" and dial 2 set to "0" with the ratio obtained when dial 1 is set to "0" and dial 2 to "X". The difference between the ratios is the line-up error between dial 1 and dial 2. It should be less than 2 steps of the last dial (2 parts in 10^7 of reading or 2 parts in 10^8 of the bridge full scale ratio of 10:1).

5.3 ALIGNMENT

The procedure given below describes the testing and alignment of the Model 9975 electronics. Because it is for corrective maintenance rather than preventative maintenance, it should be done only if a fault is found. Block diagrams (Figure 5-1 and 5-2) are provided to show the relationship between the circuit boards. The tools and test equipment required are as follows:

1. Oscilloscope with isolated inputs and a band width of 150 MHz or greater (Tektronix 454 or equivalent).

2. Board extender (Guildline PN 99752).

3. Digital voltmeter with an isolated input and an input impedance greater than 1 M.

4. Two 1 Ω standard resistors (Guildline Model 9330 or equivalent).

5. A 10 Ω standard resistor (Guildline Model 9330 or equivalent).

6. Two 100 Ω standard resistors (Guildline Model 9330 or equivalent).

7. A 1000 Ω standard resistor (Guildline Model 9330 or equivalent).

8. Trimmer potentiometer adjusting tool.

9. A 1.5 V dry cell. (Common ohmmeter on x1 Ω scale).

10. Shielded solid-copper wire (Guildline Type SCW or equivalent).

11. Decade resistor box: range - 0 to 1 kΩ
    accuracy - ±0.1%

Before beginning the alignment, the instrument should be switched off and the rear panel and 9460B Amplifier removed to allow access to the printed circuit boards. Remove all the circuit boards. Refer to figures 5-4 and 5-5, pages 5-17 and 5-18, for PCB Locations.

CAUTION

Do not remove or replace any board with power on. Ensure that all boards are inserted with the solder side facing left as the instrument is viewed from the rear. This is especially important when using the board extender because the extender connector is not keyed.

18 V Power Supply (11222) Slot 8

Using the extender, connect the board to the electronics rack and switch on the power. Observe the voltage between pins 6 and 1. It should be between 17.5 V and 17.8 V with less than 50 mV ripple and noise. Adjust the trimmer if necessary. Throughout this procedure, ignore the spikes that have a frequency of approximately 1.2 KHz. Return PCB 11222 to its proper location.

NOTE: The slots in the electronics rack are numbered from 1 to 12 reading from left to right as the instrument is viewed from the rear and the board positions are in sequence from 11225 in slot 1 to 11226 in slot 12.

Oscillator Section

The oscillator is mounted on the bottom of the slide above 9460B Amplifier. The output can be monitored on two of pins 1 through 4 of J15 on the toroid. This connector is the rear most of the toroid connectiors. Connect the oscilloscope between the pin which has two harness wires connected to it and the pin which does not have the link on it.

WARNING: The voltages on these pins are dangerous. To avoid injury to the technician and damgae to the instrument, switch the instrument off when changing connections.

Observe the square wave output from the oscillator. It should have a peak-to-peak value between 600 V and 800 V and a frequency between 600 Hz and 750 Hz.

Master Reversing Switch — Slot 6

Set the MAN/AUTO switch to MAN. Connect the board to the electronics rack and switch on the power. Measure the voltage between pins 1 and 12. It should be +15 V ±1 with less than 10 mV ripple and noise.

Measure the voltage between pins 1 and 11. It should be -15 V ±1 with less than 10 mV ripple and noise.

Monitor the voltage between pins 1 and 10. It should alternate between +3.2 V ±0.3 V and -3.2 V ±0.3 V with the CURRENT REVERSING switch.

Master Current Programmer (11225) — Slot 11

Connect the board to the rack and set the measure dials and I_x mA switch to zero. Connect the range plug with 0-10 kΩ facing up and switch the power on.

Monitor the voltage between pins 1 and 12. It should be +15 ±1 V with less than 10 mV ripple.

Monitor the voltage between pins 1 and 11. It should be -15 ±1 V with less than 10 mV ripple.

Monitor the voltage between pins 1 and 9. It should be between 0 and 5 mV with less than 5 mV ripple.

Adjust the bottom trimmer if necessary.

Monitor the voltage between pins 1 and 9 as the I_xmA switch is advanced from 0 to 0.01 mA (check both polarities). The voltage should change as follows:

CURRENT	VOLTAGE
0.001 mA	≈0.22 V
0.003 mA	≈0.66 V
0.01 mA	≈2.2 V

Set the I_xmA switch to 0 and insert the board into slot 11 in the rack.

Master Current Supply (11221) Slot 7

Connect the board to the rack and switch on the power. Monitor the voltage between pins 1 and 12. It should be 31 V ±1 V with less than 20 mV ripple.

Monitor the voltage between pins 1 and 11. It should be -31 V ±1 V with less than 20 mV ripple and noise.

With the power off, remove PCE 11225 from slot 11 and short pin 10 of the extender to ground (pin 1). Switch the power on and monitor the voltage between pins 1 and 6. It should be between 0 and 5 mV with less than 20 mV noise.

Move the ground lead from pin 10 to pin 8. Monitor the voltage between pins 1 and 4. It should be between 0 and 5 mV with less than 10 mV noise. Adjust the 1 kΩ trimmer if necessary.

Replace PCB 11225 and monitor the voltage between pins 1 and 6 on PCB 11221. It should be between 0 and 15 mV with less than 10 mV noise. Advance the I_xmA switch to 0.01 mA and compare the voltages at each position with those given below:

CURRENT	VOLTAGE
0.001 mA	≈0.47 V
0.003 mA	≈1.48 V
0.01 mA	≈4.7 V

Set the I_xmA switch to 0, remove the ground lead and insert the board into the rack.

Current Magnitudes

Set the measure dials to 0, the x1/x$\sqrt{2}$ switch to x1 and connect a 10 Ω standard resistor and a decade resistance box in series with it to the R_x C_1 and C_2 posts. Connect the DVM across the standard resistor (the C_2 post is positive if the CURRENT REVERSING switch is set to A).

Switch the power on and set the I_xmA switch to 10 mA. The voltmeter should read either 100 mV ±0.5 mV or -100 mV ±0.5 mV, depending on the position of the CURRENT REVERSING switch. Operate the switch to ensure that both polarities are available.

Without switching the power off, remove PCB 11220 (slot 6) and note the voltmeter reading. Adjust the bottom trimmer on PCB 11225 (slot 11) to obtain a reading of ±0.05 mV ±0.02 mV.

Replace PCB 11220. The voltmeter reading should return to ±100 mV ±0.5 mV. Set the decade box resistance to 100 Ω and observe the voltmeter reading. Adjust the top trimmer on PCB 11225 until switching the resistance box from 0 to 100 Ω and back again changes the reading by less than 0.5%. Reverse the current and check the voltmeter reading again while switching the resistance box from 0 to 100 Ω. It should change by less than 0.5%. Set the reversing switch to A and, if necessary, adjust the bottom trimmer on PCB 11220 until the voltage is 100 mV ±0.5 mV. Repeat this step with the switch set to B and adjust the upper trim pot if necessary.

Check both polarities of the voltage across the 10 Ω resistor with the x1 x$\sqrt{2}$ switch set to x$\sqrt{2}$. It should be ±141 mV ±0.5 mV.

Check the R_x currents by measuring the voltages across the standard resistors listed below with the x1 x$\sqrt{2}$ switch set to x1. Check both polarities.

CURRENT (mA)	STANDARD RESISTOR (Ω)	VOLTAGE (mV)	
100	10	1000	±5
30	10	316.2	±1.5
10	10	100	±0.5
3	10	31.62	±0.15
1	100	100	±0.5
0.3	100	31.62	±0.15
0.1	1000	100	±0.5
0.03	1000	31.62	±0.15
0.01	1000	10	±0.05
0.003	1000	3.16	±0.015
0.001	1000	1	±0.005

Set the I_x mA switch to zero and switch the instrument off.

Reversing Timer (11223) Slot 9

Connect the board to the rack, set the MAN/AUTO switch to AUTO, the REV RATE switch to 16, the I_x mA switch to 1, short circuit the R_x C1 and C2 terminals and switch the instrument on. Time 10 cycles of the I_x mA meter and calculate the average cycle time. Each cycle should take 16 s ±0.8 s.

Set the REV RATE switch to 8 and monitor the voltage between pins 1 and 7 and pins 1 and 5. It should be low for 1 s and high for 7 s.

Set the REV RATE switch to 4 and monitor the signals between pins 1 and 7 and pins 1 and 3. They should be low for 1 s and high for 3 s.

Measure the pulses between pins 1 and 11 and pins 1 and 10. They should be between 0.95 s and 1.05 s at 19 V to 20 V p-p.

Set the I_xmA switch to 0 and insert the PCB into slot 9.

Flux Detector Amplifier (11215) Slot 1

Connect the board to the rack and a 10 Ω standard resistor to the R C1 and C2 terminals. Set the MAN/AUTO switch to MAN, the I_xmA switch and all measure dials to 0 and monitor the voltage between pins 1 and 5 on the PCB. The waveform should have a value between 1 V and 20 V and a frequency equal to the oscillator frequency.

Monitor the voltage between pins 1 and 8. Set the I mA switch to 10 mA and adjust the last two measure dials to centre the ATB meter. If this requires more than 3 steps of the x10^{-6} dial, shunt one of the 40 kΩ balancing resistors (refer to dwg. 11215.02.02) as necessary. The voltage between pins 1 and 8 should be between 0 and ±40 mV superimposed on a 0 to 5 mV square wave. The sign of the offset voltage is controlled by the CURRENT REVERSING switch.

Turn the x10^{-5} dial to the next higher position to add 100 μA.turns to the measurement. The DVM should indicate between 90 and 140 mV. Turn the x10^{-5} dial back to its original position and turn the x10^{-6} dial to the next higher position to add 10 μA.turns to the measurement. The DVM should indicate between 9 and 14 mV and the ATB meter needle should move one division. Note that because the ATB meter response is nonlinear, the reading obtained by changing the 10^{-5} dial setting is irrelevant.

Insert PCB 11215 into slot 1 in the rack and remove the 10 Ω standard resistor.

Slave Current Supply (11217) Slot 3

Connect the board to the rack, short circuit the R_s C1 and C2 terminals and set the I_xmA switch and all measure dials to 0. Switch on the power. Measure the voltage between pins 1 and 12. It should be 31 V ±1 V with less than 20 mV noise.

Measure the voltage between pins 1 and 11. It should be -31 V ±1 V with less than 20 mV ripple.

Monitor the voltage between pins 1 and 6 and adjust the COMP BAL control on the side-panel to centre the ATB meter. The oscilloscope should indicate between 0 and 5 mV with less than 10 mV noise.

Insert PCB 11217 into slot 3 of the rack.

Tracking Control (11216) Slot 2

Connect the board to the rack, set the MAN/AUTO switch to AUTO, the REV RATE switch to 4, connect a pair of 1 Ω standard resistors to R_s and R_x and set the R_s switch to 1 Ω.

Turn the HIGH TRACK control completely clockwise, switch the power on and centre the ATB meter with the COMP BAL control.

Measure the voltage between pins 1 and 12. It should be +15 V ±1 V with less than 10 mV ripple.

Measure the voltage between pin 1 and the junction of the 313 kΩ and 10 kΩ resistor (refer to dwg. 11216.02.02). It should be between 0 and 5 mV with less than 5 mV ripple. Remove the oscilloscope or DVM.

Set the x1 and x10^{-1} dials to maximum and adjust the lower trimmer on PCB 11216 to centre the ATB meter reading.

Set the x1 dial to zero and centre the HIGH TRACK control by turning it 5 turns counterclockwise.

Set the I_xmA switch to 1 mA and observe the ATB meter. There should not be any needle motion as the I_xmA meter reverses. If there is, adjust the trimmer on PCB 11217 (slot 3).

Set the I_xmA switch and the x10^{-1} dial to zero. Centre the ATB meter reading with the COMP BAL control.

Set the x1 and x10^{-1} dials to maximum and centre the ATB meter needle by readjusting the lower trimmer on PCB 11216 if necessary.

Set the x1 dial to 0 and the I_xmA switch to 10 mA. If the ATB meter needle deflects with current reversals, readjust the trimmer on PCB 11217. Set the $x10^{-1}$ dial to 0 and the I_xmA switch to 100 mA. If the ATB meter needle deflects with current reversals, adjust the top trimmer on PCB 11216.

Set the I_xmA switch to 0 and insert PCB 11216 into slot 2.

<u>Lamp Voltage Supply (11226)</u> Slot 12

Connect the board to the rack and switch the power on.

Measure the voltage between pins 1 and 2. It should be 2.0 V ±0.2 V if the Ohmite resistor below the trimmer is 3 Ω and 1.75 V ±0.2 V if the resistor is 2.4 Ω. Adjust the trimmer if necessary.

Insert the PCB into slot 12 in the rack.

<u>Nanovolt Detector Amplifier (11218)</u> Slot 4

Connect the board to the rack, and switch the power on.

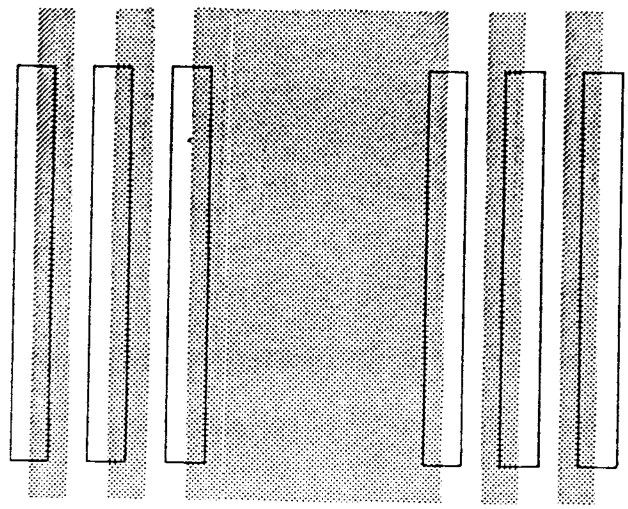
Measure the voltage between pins 1 and 11. It should be -15 V ±1 V with less than 10 mV ripple.

Measure the voltage between pins 1 and 12. It should be 15 V ±1 V with less than 10 mV ripple.

Measure the voltage between pins 1 and 8. Adjust the 9460B zero control until the oscilloscope or DVM indicates 0 V ±5 mV.

Observe the light pattern on the 9460B photocells by looking through the port in the instrument case. The light pattern should lock into the grid when the OUT/OCA switch is set to PCA.

> <u>NOTE:</u> The bright pattern at the rear of the 9460B is the wrong one to check. The correct one is opposite the port and relatively dim. The desired pattern is shown on the following page.



MODEL 9460B

LIGHT PATTERN

Error Summing Amplifier (11224) Slot 10

Connect the board to the rack and replace the 1 Ω standard resistors with 100 Ω standard resistors.

Set the MAN/AUTO switch to AUTO, the REV RATE switch to 8, the R_x Ω switch to 100, the DEMODULATOR D1/D2 switch D1, the x1 dial to 1, and the I_x mA switch to 0.

Switch the power on and then adjust the COMP BAL control to centre the ATB meter. Centre the galvanometer needle with the GALV BALANCE control. Set the I_x mA switch to 1 mA and adjust the HIGH TRACK control to zero the ATB meter. Adjust the measure dials to balance the galvanometer reading at the highest possible sensitivity. Offset the ATB meter 3 divisions by adjusting the HIGH TRACK control. If the galvanometer reading changes, adjust the trimmer.

Insert PCB 11224 into slot 10 in the rack.

Unbalance Signal Demodulator (11219) Slot 5

Connect the board to the rack and remove PCB 11225 from slot 10.

Set the GALVANOMETER D1/D2 switch to D2, the GALVANOMETER SENSITIVITY switch to x1 and the I_x mA switch to 0. Switch the power on.

Measure the voltage between pins 1 and 12. It should be +15 V ±1 V with less than 10 mV ripple and noise.

Measure the voltage between pins 1 and 11. It should be -15 V ±1 V with less than 10 mV ripple and noise.

Set the MAN/AUTO switch to MAN. Measure the voltage between pins 1 and L (component side).

The voltage should be between 0 and 5 mV.

Measure the voltage between pins 1 and M. The voltage should be between 0 and 5 mV.

Measure the voltage between pins 1 and 10. It should be between 0 and 5 mV, and the galvanometer needle should be centered. Adjust the REC ZERO control if necessary.

Set the MAN/AUTO switch to AUTO and check the voltage between pins 1 and 10. It should be between 0 and 5 mV.

Connect a 1.5 V dry cell between pins 1 and 7. Wait 30 s and adjust the trimmer until the voltage between pins 1 and 10 is between 0 and 5 mV. Remove the dry cell and check the galvanometer reading. It should be 0.

Insert PCB 11219 and PCB 11224 into slots 5 and 10 and replace the rear panel. The alignment procedure is complete.

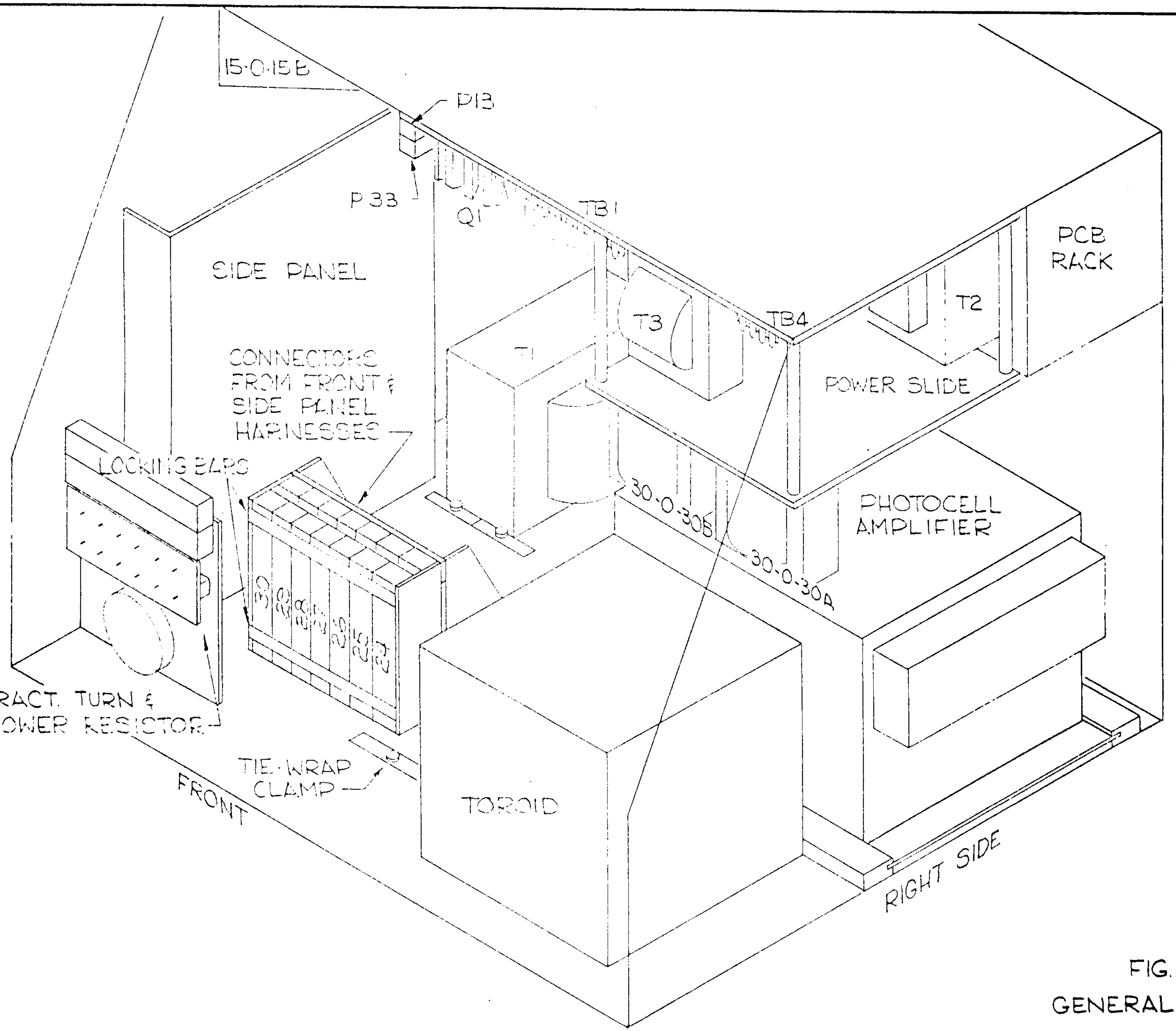


FIG. 5-4
GENERAL ASSEMBLY
FRONT VIEW

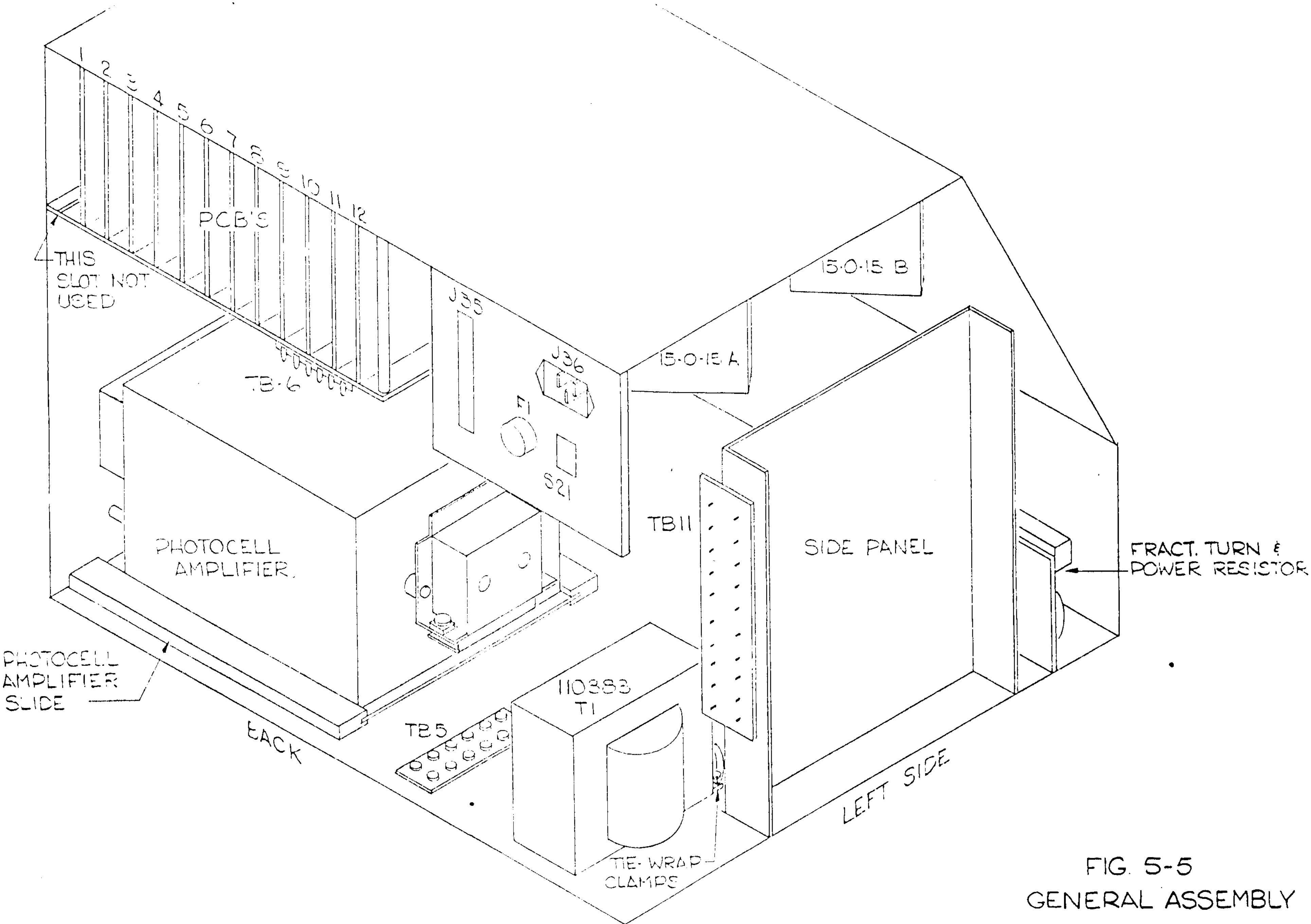


FIG. 5-5
GENERAL ASSEMBLY
REAR VIEW

SECTION 6

PCB COMPONENT LOCATION AND SCHEMATIC DIAGRAMS

6.1 LIST OF DRAWINGS

	Drawing Number	Description
PL	11215.02.02	Flux Detector Amplifier PCB, parts list
	11215.02.02	Flux Detector Amplifier PCB, component location
PL	11216.02.02	Tracking Control PCB, parts list
	11216.02.02	Tracking Control PCB, component location
PL	11217.03.02	Slave Current Supply PCB, parts list
	11217.03.02	Slave Current Supply PCB, component location
PL	11218.02.02	Nanovolt Detector Amplifier PCB, parts list
	11218.02.02	Nanovolt Detector Amplifier PCB, component location
PL	11219.03.02	Unbalance Signal Demodulator PCB, parts list
	11219.03.02	Unbalance Signal Demodulator PCB, component location
PL	11220.02.02	Master Reversing Control PCB, parts list
	11220.02.02	Master Reversing Control PCB, component location
PL	11221.02.02	Master Current Supply PCB, parts list
	11221.02.02	Master Current Supply PCB, component location
PL	11222.02.02	18 V Power Supply PCB, parts list
	11222.02.02	18 V Power Supply PCB, component location
PL	11223.02.02	Reversing Timer PCB, parts list
	11223.02.02	Reversing Timer PCB, component location
PL	11224.02.02	Error Summing Amplifier PCB, parts list
	11224.02.02	Error Summing Amplifier PCB, component location
PL	11225.02.02	Master Current Programmer PCB, parts list
	11225.02.02	Master Current Programmer PCB, component location
PL	11226.01.02	Lamp Voltage Supply PCB, parts list
	11226.01.02	Lamp Voltage Supply PCB, component location
	16128.01.04	General Schematic
	16128.02.04	General Schematic Rs ≤ 1 kΩ

PARTS LIST

GUILDLINE INSTRUMENTS LTD

FAM TREE KEY PCB

LIST NUMBER 11215.02.02

SHEET 1 OF 1 SHEET

DRN L.M. CKD

DATE 4/4/77 APP

TITLE Flux Detector Amplifier PCB Assembly

MODEL 9932, 9975

REV	ECN	DATE	CKD	REV	ECN	DATE	CKD	REV	ECN	DATE	CKD
M	663										
N	1178										
P	1225										
R	1510										

REV	ITEM	DESCRIPTION	QTY	CODE	MANUFACTURER	PART NUMBER	CIRCUIT REF
	1	Printed Circuit Board	1	PS		11215.02.07 Rev. B	
	2	Amplifier	1	PS		LM741CN	A1
	3	Diode	4	PS		1N459	CR1 - 4
	4	Diode	2	PS		1N270	CR5, 6
	5	Diode	2	PS		1N965B	VR1, 2
	6	Resistor Carbon $\frac{1}{2}$W 100 ohms 5%	1	PS		CR37	R5
R	7	**Delete**					
	8	**Resistor Carbon $\frac{1}{2}$W 1K 5%**	1	PS		CR37	R11
	9	Resistor Carbon $\frac{1}{2}$W 18K 5%	1	PS		CR37	R9
	10	Resistor Carbon $\frac{1}{2}$W S.O.T. 5%	3	PS		CR37	R1, 2, 6
	11	Resistor Carbon $\frac{1}{2}$W 4.7K 5%	1	PS		CR37	R7
	12	**Delete**					
	13	Resistor Carbon $\frac{1}{2}$W 47 ohms 5%	1	PS		CR37	R10
	14	Resistor 40.2K 1%	2	PS	I.R.C.	MEBTO	R3, 4
P	15	Capacitor 6.8uf 63V	1	PS	Siemens	B32110-F9685	C3
	16	Capacitor 15uf 20V	2	PS		CSR13E156K-L	C1, 2
	17	Capacitor .47uf 250V	1	PS	Philips	281ABA470K	C4
	18	Capacitor .1uf 250V	1	PS	Philips	281ABA100K	C5

PARTS LIST

GUILDLINE INSTRUMENTS LTD

FAM TREE KEY PCB

TITLE	
TITLE	Tracking Control PCB Assembly
MODEL	9975

REV	ECN	DATE	CKD	REV	ECN	DATE	CKD	REV	ECN	DATE	CKD
Q	876			U	1428						
R	1178										
S	1192										
T	1225										

LIST NUMBER 11216.02.02

SHEET 1 OF 1 SHEETS

DRN L.M. CKD

DATE 4/4/77 APP

REV	ITEM	DESCRIPTION	QTY	CODE	MANUFACTURER	PART NUMBER	CIRCUIT REF
S	1	Printed Circuit Board	1	PS		11216.02.07 Rev. C	
	2	Resistor Carbon $\frac{1}{2}$W 510 ohms 5%	1	PS		CR37	R6
	3	Resistor Carbon $\frac{1}{2}$W 33 ohms 5%	1	PS		CR37	R4
	4	Resistor Carbon $\frac{1}{2}$W 47K 5%	1	PS		CR37	R2
	5	Resistor Carbon $\frac{1}{2}$W 10K 5%	3	PS		CR37	R5, 11, 12
	6	Resistor Carbon $\frac{1}{2}$W 3.3K 5%	1	PS		CR37	R7
	7	Resistor Carbon $\frac{1}{2}$W 2.7K 5%	1	PS		CR37	R3
	8	Resistor Carbon $\frac{1}{2}$W 270K 5%	1	PS		CR37	R9
	9	Resistor Carbon $\frac{1}{2}$W 47 ohms 5%	2	PS		CR37	R10, 13
T	10	Capacitor .luf 250V	1	PS	Philips	C281AB/A100K	C1
	11	Amplifier	2	PS		LM741CN	A2, 3
	12	Operational Amplifier	1	PS	Analog	40K	A1
U	13	Trimpot 50K	1	PS		RV-450-20-50K	R8
U	14	Trimpot 10K	1	PS		RV-450-20-10K	R1

PARTS LIST — GUILDLINE INSTRUMENTS LTD

FAM TREE KEY PCB

TITLE: Slave Current Supply

MODEL: 9975

LIST NUMBER: 11217.03.02

SHEET 1 OF 1 SHEETS

DRN EKoehler | CKD
DATE 15-11-76 | APP IM

REV	ECN	DATE	CKD	REV	ECN	DATE	CKD	REV	ECN	DATE	CKD
N	1126	15-11-76		S	1428						
P	1178										
Q	1225										
R	1330										

REV	ITEM	DESCRIPTION	QTY	CODE	MANUFACTURER	PART NUMBER	CIRCUIT REF
N	1	Printed Circuit Board	1			11217.01.07 Rev F	
P	2	Resistor Carbon ½W 10K 5%	3			CR37	R1, 3, 5
	3	Resistor Carbon ½W 39K 5%	2			CR37	R7, 10
	4	Resistor Carbon ½W 1K 5%	2			CR37	R8, 9
	5	Resistor Carbon ½W 47 ohms 5%	2			CR37	R11, 12
	6	Resistor Carbon ½W 2.2M 5%	1			CR37	R4
	7	Resistor Carbon ½W 22K 5%	1			CR37	R6
	8	Transistor	1			2N4923	Q1
	9	Transistor	1			2N4920	Q2
	10	Capacitor 22pf	1		Centralab	DD220	C3
	11	Capacitor .1µf 250V	1		Philips	C281AB/A100K	C1
	12	Capacitor 39pf	1		Centralab	DD390	C2
	13	Diode	2			1N459	CR1, 2
	14	Integrated Circuit	1		N.S.	LH0004CH	A1
	15	Trimpot 20K	1		I.R.C.	600-20-20K	R2
	16	Heatsink	1	F.S.	Guildline	14847.01.10	
	17	Insulator	1	F.S.	Guildline	10023.01.10	
R	18	10 Pin Socket	1		Robinson & Nugent	SD51710-23	
S	19	Washer, Mica	2			B52600F003	

PARTS LIST	GUILDLINE INSTRUMENTS LTD	FAM TREE KEY PCB
TITLE: Nanovolt Detector Amp. PCB Assembly		LIST NUMBER: 11218.02.02
MODEL: 9975		SHEET 1 OF 1 SHEETS
		DRN L.M. CKD
		DATE 4/4/77 APP

REV	ECN	DATE	CKD	REV	ECN	DATE	CKD	REV	ECN	DATE	CKD
J	896										
K	1178										
L	1225										

REV	ITEM	DESCRIPTION	QTY	CODE	MANUFACTURER	PART NUMBER	CIRCUIT REF
	1	Printed Circuit Board	1	PS		11218.02.07 Rev. B1	
	2	Resistor Carbon $\frac{1}{2}$W 1K 5%	3	PS		CR37	R3, 8, 10
	3	Resistor Carbon $\frac{1}{2}$W 10K 5%	1	PS		CR37	R7
	4	Resistor Carbon $\frac{1}{2}$W 100K 5%	2	PS		CR37	R4, 9
	5	Resistor Carbon $\frac{1}{2}$W 47K 5%	1	PS		CR37	R1
	6	Resistor Carbon $\frac{1}{2}$W 22K 5%	1	PS		CR37	R6
	7	Resistor Carbon $\frac{1}{2}$W 47 ohms 5%	2	PS		CR37	R2, 5
	8	Capacitor .47uf 250V	1	PS	Philips	281ABA470K	C2
	9	Capacitor .022uf 250V	1	PS	Philips	281ABA22K	C1
	10	Diode	2	PS		1N705A	VR1, 2
	11	Amplifier	2	PS		LM741CN	A1, 2

Rev T ECN No 2106

Appr Date 23/06/83

BILL OF MATERIALS
GUILDLINE INSTRUMENTS LTD.

Bill No. PL11219.03.02 Sht 1 of 1

Title Demodulator PCB

Model Number 9975

Code	Qty	Stock Number	Description	Cct Reference	Mfr Part Number	Mfr
S	1	11219.03.07C	Printed Circuit Board			
F	8	737-01899	Resistor	R1, 3-7, 12, 17	CR37 TOL5 470KΩ	Philips
F	4	737-01351	Resistor	R2, 14, 15, 19	CR37 TOL5 10KΩ	Philips
F	1	737-01314	Resistor	R13	CR37 TOL5 6.8KΩ	Philips
F	1	737-03399	Resistor	R18	CR37 TOL5 1MΩ	Philips
F	4	737-01200	Resistor	R8-11	CR37 TOL5 1KΩ	Philips
S	1	300-05025	Variable Resistor	R16	600-20-5K	I.R.C.
S	2	045-00962	Capacitor	C2, 3	C280AE/A680K	Philips
S	1	049-11050	Capacitor	C1	UK 50-104	Centralab
S	2	075-46142	Diode	CR1, 2	1N459	
S	1	200-40350	I.C. Linear	A3	LM741CN	
S	4	801-70100	Transistor	Q1-4	2N4351	
S	2	200-40198	I.C. Linear	A1, 2	40J	Analog

BILL OF MATERIALS

GUILDLINE INSTRUMENTS LTD.

ev Q ECN No 2294

pr Date 23/06/83

Bill No. PL 11220.02.02 Sht 1 of 1

Title Master Reversing Control PCB Assembly

Model Number 9975

de	Qty	Stock Number	Description	Cct Reference	Mfr Part Number	Mfr
S	1	11220.02.07B	Printed Circuit Board			
F	4	737-01314	Resistor	R10, 11, 16, 17	CR37 TOL5 6.8KΩ	Philips
F	2	737-01394	Resistor	R6, 7	CR37 TOL5 22KΩ	Philips
F	2	737-01448	Resistor	R13, 14	CR37 TOL5 47KΩ	Philips
F	1	737-00199	Resistor	R2	CR37 TOL5 47Ω	Philips
F	2	737-01415	Resistor	R9, 19	CR37 TOL5 27K	Philips
S	2	038-01055	Capacitor	C1, 4	TE 1301	Sprague
S	2	041-00840	Capacitor	C2, 3	TAG 4.7/35	I.T.T.
S	4	075-46142	Diode	CR1-4	1N459	
S	4	801-80300	Transistor	Q1-4	2N3905	
S	1	200-40350	I.C. Linear	A1	LM741CN	
F	6	737-01281	Resistor	R4, 5, 15, 18	CR37 TOL5 4.7KΩ	Philips
S	2	300-05025	Variable Resistor	R1, 3	600-20-5K	VRN
[illegible]	2	041-01269	Capacitor	C5, C6	TAG 10/35	ITT

PARTS LIST	GUILDLINE INSTRUMENTS LTD	FAM TREE KEY PCB
TITLE: Master Reversing Control PCB Assembly		LIST NUMBER 11220.02.02
MODEL 9975		SHEET 1 OF 1 SHEETS
		DRN L.M. CKD
		DATE 4/4/77 APP

REV	ECN	DATE	CKD	REV	ECN	DATE	CKD	REV	ECN	DATE	CKD
M	876										
N	1178										
P	1225										

REV	ITEM	DESCRIPTION	QTY	CODE	MANUFACTURER	PART NUMBER	CIRCUIT REF
	1	Printed Circuit Board	1	PS		11220.02.07 Rev. B	
	2	Resistor Carbon ½W 6.8K 5%	4	PS		CR37	R10, 11, 16, 17
	3	Resistor Carbon ½W 22K 5%	2	PS		CR37	R6, 7
	4	Resistor Carbon ½W 47K 5%	2	PS		CR37	R13, 14
	5	Resistor Carbon ½W 47 ohms 5%	1	PS		CR37	R2
	6	Resistor Carbon ½W 27K 5%	2	PS		CR37	R9, 19
	7	Capacitor 2uf 50V	2	PS	Sprague	TE 1301	C1, 4
	8	Capacitor 4.7uf 35V	2	PS	I.T.T.	TAG 4.7/35	C2, 3
	9	Diode	4	PS		1N459	CR1-4
	10	Transistor	4	PS		2N3905 T092	Q1-4
	11	Amplifier	1	PS		LM741CN	A1
	12	Resistor Carbon ½W 4.7K 5%	6	PS		CR37	R4, 5, 15, 18
	13	Trimpot 5K	2	PS		RV-600-20-5K	R1, 3

Rev V ECN No 2106

Appr Date 23/06/83

BILL OF MATERIALS
GUILDLINE INSTRUMENTS LTD.

Bill No. PL11221.02.02 Sht 1 of 1

Title Master Current Supply

Model Number 9975

Code	Qty	Stock Number	Description	Cct Reference	Mfr Part Number	Mfr
S	1	11221.02.07H	Printed Circuit Board			
F	2	737-01351	Resistor	R9, 10	CR37 TOL5 10KΩ	Philips
F	2	737-01437	Resistor	R5, 8	CR37 TOL5 39KΩ	Philips
F	2	737-02975	Resistor	R14, 15	CR37 TOL5 3.3MΩ	Philips
F	3	737-01200	Resistor	R3, 6, 7	CR37 TOL5 1KΩ	Philips
F	1	737-00166	Resistor	R12	CR37 TOL5 33Ω	Philips
F	2	737-00199	Resistor	R1, 2	CR37 TOL5 47Ω	Philips
F	1	737-01340	Resistor	R15	CR37 TOL5 9.1KΩ	Philips
* F	1	760-00760	Resistor, 20k 1/4w	R13	RN60D 2002F	
F	1	737-01481	Resistor	R4	CR37 TOL5 68KΩ	Philips
S	1	200-40264	I.C. Linear	A2	LM302H	
S	1	200-40132	I.C. Linear	A1	LH0004CH	N.S.
S	1	300-05015	Variable Resistor	R11	600-20-1K	VRN
S	1	801-75650	Transistor	Q1	2N4923	
S	1	801-80450	Transistor	Q2	2N4920	
S	2	075-46142	Diode	CR1, 2	1N459	
F	2	049-00390	Capacitor	C1, 2	DD390	Centralab
F	1	049-00220	Capacitor	C3	DD220	Centralab
S	1	158-01060	Heatsink		209-CB	Delta-T
S	1	13898.01.10	Heatsink			Guildline
S	1	13900.01.10	Pillar			Guildline
S	1	410-04004	Socket		SD51710-23	Robinson-Nugent
F	2	150-11032	Washer		B52600F003	Motorola

PARTS LIST	GUILDLINE INSTRUMENTS LTD	FAM TREE KEY PCB
TITLE: 18V DC Power Supply PCB Assembly		LIST NUMBER 11222.02.02
MODEL 9975, 9932		SHEET 1 OF 1 SHEETS
		DRN L.M. CKD
		DATE 4/4/77 APP

REV	ECN	DATE	CKD	REV	ECN	DATE	CKD	REV	ECN	DATE	CKD
H	714										
J	1178										
K	1225										

REV	ITEM	DESCRIPTION	QTY	CODE	MANUFACTURER	PART NUMBER	CIRCUIT REF
	1	Printed Circuit Board	1	PS		11222.02.07 Rev. B	
	2	Transistor	1	PS		2N4920	Q1
	3	Trimpot 500 ohms	1	PS		RV-600-20-500	R3
	4	Bridge Rectifier	1	PS		BY179	CR1
	5	Amplifier	1	PS	N.S.	LM305H	A1
	6	Resistor Carbon $\frac{1}{2}$W 1 ohm 5%	1	PS		CR37	R1
	7	Resistor Carbon $\frac{1}{2}$W 1.2K 5%	1	PS		CR37	R4
	8	Resistor Carbon $\frac{1}{2}$W 15K 5%	1	PS		CR37	R2
	9	Capacitor 470uf 40V	1	PS	Philips	437ETG470	C1
	10	Capacitor 4.7uf 35V	1	PS	I.T.T.	TAG 4.7/35	C2
	11	Capacitor 47pf	1	PS	Centralab	DD470	C3
	12	Heatsink	1	FS	Guildline	13587.01.10	

PARTS LIST

GUILDLINE INSTRUMENTS LTD

FAM TREE KEY PCB

TITLE: Reversing Timer PCB

MODEL: 9975

REV	ECN	DWN	CHK	CHK
R	1177	LM	✓	
S	1225	TH	✓	✓

LIST NUMBER: 11223.02.02

SHEET 1 OF 1 SHEETS

DATE 17-3-77 DWN LM

CHKD ✓ APVD IM

REV	ITEM	DESCRIPTION	QTY	CODE	MANUFACTURER	PART NUMBER	CIRCUIT REF
	1	Printed Circuit Board	1	PS		11223.02.07 Rev. B	
	2	Resistor 6.8K	6	PS		CR37	R3,6,7,10,12,15
	3	Resistor 100K	1	PS		CR37	R9
	4	Resistor 12K	6	PS		CR37	R1,2,8,11,16,17
	5	Resistor 15K	2	PS		CR37	R4, 13
	6	Resistor 68K	2	PS		CR37	R5, 14
	7	Capacitor 22uf 35V	2	PS		CSR13F226K-L	C1, 5
	8	Capacitor 82uf 20V	2	PS		CSR13E826K	C2, 4
	9	Capacitor .01uf 100V	1	PS	Philips	281CGA10K	C3
	10	Diode	4	PS		1N459	CR1 - 4
R	11	Diode	2	PS		1N705	VR1, 2
	12	Transistor	2	PS		2N3903 T092	Q1, 8
	13	Transistor	4	PS		2N3905 T092	Q2, 3, 6, 7
	14	Transistor	2	PS		2N929	Q4, 5

PARTS LIST

GUILDLINE INSTRUMENTS LTD

TITLE	REV	ECN	DATE	CKD	REV	ECN	DATE	CKD	REV	ECN	DATE	CKD	FAM TREE KEY PCB
Error Summing Amp. PCB Assembly	J	663											LIST NUMBER 11224.02.02
	K	1178											SHEET 1 OF 1 SHEETS
MODEL 9975	L	1225											DRN L.M. CKD
													DATE 4/4/77 APP

REV	ITEM	DESCRIPTION	QTY	CODE	MANUFACTURER	PART NUMBER	CIRCUIT REF
	1	Printed Circuit Board	1	PS		11224.02.07 Rev. B	
	2	Resistor Carbon $\frac{1}{4}$W 47 ohms 5%	2	PS		CR37	R4, 7
	3	Resistor Carbon $\frac{1}{2}$W 1K 5%	1	PS		CR37	R1
	4	Resistor Carbon $\frac{1}{4}$W 10K 5%	2	PS		CR37	R3, 6
	5	Resistor Carbon $\frac{1}{2}$W 3.9K 5%	1	PS		CR37	R5
	6	Capacitor .1uf 250V	2	PS	Philips	281ABA100K	C2, 4
	7	Capacitor 10uf 25V	1	PS	Siemens	B32110-C3106-M	C1
	8	Capacitor 180pf	1	PS	Centralab	DD181	C3
	9	Amplifier	2	PS		LM741CN	A1, 2
	10	Trimpot 20K	1	PS		RV-600-20-20K	R2

PARTS LIST

GUILDLINE INSTRUMENTS LTD

FAM TREE KEY PCB

TITLE: Master Current Programmer PCB Assembly

MODEL: 9975

LIST NUMBER: 11225.02.02

SHEET 1 OF 1 SHEETS

DRN L.M. | CKD | DATE 4/4/77 | APP

REV	ECN	DATE	CKD
L	566		
M	1178		
N	1225		

REV	ITEM	DESCRIPTION	QTY	CODE	MANUFACTURER	PART NUMBER	CIRCUIT REF
	1	Printed Circuit Board	1	PS		11225.02.07 Rev. B	
	2	Resistor Carbon ¼W 33 ohms 5%	1	PS		CR37	R8
	3	Resistor Carbon ¼W 10K 5%	2	PS		CR37	R2, 5
	4	Resistor Carbon ¼W 3.3M 5%	1	PS		CR37	R4
	5	Resistor Carbon ¼W 47 ohms 5%	2	PS		CR37	R1, 7
N	6	Resistor 15K	1	PS	GR	8E16A	R9
	7	Trimpot 10K	1	PS		RV-600-20-10K	R6
	8	Amplifier	2	PS		LM741CN	A1, 2
	9	Trimpot 2K	1	PS		RV-600-20-2K	R3

PARTS LIST	GUILDLINE INSTRUMENTS LTD	FAM TREE KEY PCB
TITLE: Lamp Voltage Supply PCB Assembly		LIST NUMBER 11226.01.02
MODEL 9975		SHEET 1 OF 1 SHEETS
		DRN Lockhart · CKD · DATE 18-10-76 · APP IM

REV	ECN	DATE	CKD
J	876		
K	1126	26-10-76	
L	1225		

REV	ITEM	DESCRIPTION	QTY	CODE	MANUFACTURER	PART NUMBER	CIRCUIT REF
	1	Printed Circuit Board	1	PS		11226.01.07 Rev. B	
	2	Capacitor 100pf	1	PS	Centralab	DD101	C3
	3	Capacitor 470uf 40V	2	PS	Philips	437ETG470	C1, 2
	4	Capacitor 4.7uf 35V	1	PS	I.T.T.	TAG 4.7/35	C4
	5	Transistor	1	PS		2N4402	Q1
	6	Trimpot	1	PS		RV-600-20-500	R5
	7	Integrated Circuit	1	PS	N.S.	LM305H	A1
	8	Resistor 68 ohms	1	PS		CR37	R1
	9	Resistor 56 ohms	1	PS		CR37	R2
	10	Resistor 470 ohms	1	PS		CR37	R3
	11	Resistor 2.2K	1	PS		CR37	R6
	12	Resistor 3.3K	1	PS		CR37	R4
K	13	Resistor 3 ohms	1	PS	Ohmite	2833	R7

ADDENDUM

DATE: October 29th, 1984.

MANUAL: 9975TM-C-01

Changes:

1. Throughout the manual when referring to the current Ix (mA) settings, the positions labelled .003, .03, .3, 3 and 30 mA are actually .003162, .03162, .3162, 3.162 and 31.62 mA respectively.

2. On page 1-3, change the text, after the heading Test Currents, to read as follows:

   From internal supply, 30 V compliance:

   Four-Terminal Measurements of 0.001, 0.003, 0.01, 0.03, 0.1, 0.3, 1, 3, 10, 30 and 100 mA.

   Two-Terminal Measurements of 0.001 mA = 2 V, 0.003 mA = 6.3 V, 0.01 mA = 20 V.

   All currents and voltages may be multiplied by $\sqrt{2}$ (double power).

   Accuracy: ±1.5%

   Stability: ±0.5%

   Terminals with 20 V compliance are provided for programming an external power supply.

NOTE

The actual current output at 0.3, 3 and 30 mA settings is 0.3162, 3.162 and 31.62 mA respectively.