BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

RECORD

RECORD 1985/39

HANDBOOKS

for

MPE-1 PHOTO-ELECTRONIC MAGNETOMETER (HORIZONTAL)

MPE-2 PHOTO-ELECTRONIC MAGNETOMETER (VERTICAL)

and

MCC-1 MAGNETOMETER CONTROLLER

(3rd Edition)

by

K. J. Seers

and

G. W. Black

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PREFACE TO THIRD EDITION

Since the 1984 installation at Macquarie Island, a number of design innovations have been incorporated:

* Electronic temperature compensation.

* Provision for introducing an output offset to cater for field variations which are asymmetrical about the mean value.

* A brighter LED to improve signal-to-noise ratio.

* Better control of a.c. and d.c. gain distribution to cover wide variations in magnet and optical sensitivities.

As this handbook edition is being written, new circuit boards incorporating these changes are under construction. The intention is to test the new boards during the Antarctic training period at Canberra Magnetic Observatory, and to upgrade the Macquarie Island units later this year and those at Mawson in 1986.

A further three-component system is under construction for Latrobe University and will be installed at the Toolangi Magnetic Observatory. This system will employ the existing La Cour H Variometers rather than QHMs for the horizontal field components. The La Cour H Variometers will be modified by removing the two prisms and lowering the fibre and magnet to allow greater reflected light intensity. An adaptor ring permits the use of a lens identical with that used for the Z Balance. The La Cour mounting arrangements differ slightly from those used for the QHM. All references in the text to QHMs should be taken to refer to La Cour H Variometers for the Toolangi installation.

Some minor textual errors have been corrected in this edition.

August 1985

PREFACE TO SECOND EDITION

The first edition of these handbooks was issued as BMR Record No. 83/12. As foreshadowed in the Preface to that edition, two MPE-1 components (X & Y) with Controller, MCC-1, were installed at Mawson in mid 1983, and an identical system was installed at Macquarie Island in October of that year.

During 1984, the principle employed in utilizing the QHM in the MPE-1 was applied to the La Cour Z-Balance, resulting in a vertical component photo-electronic magnetometer, designated MPE-2. Thus a three-component system became operational at Macquarie Island in October 1984, and a Z-component will be added to the Mawson installation in 1985.

A physically shorter, cheaper, but more sensitive photodiode was tried successfully in the MPE-2. This will become standard in all components, has already been installed in the Z component at Macquarie Island, and will be installed in the Mawson Z component in 1985. To take advantage of the higher performance of this photodiode, redesign of the electronic feedback circuit will be necessary. When this is done, new circuit boards will be installed in all units as opportunities arise, and a third edition of the handbook (or amendments) will be issued.

Three-component operation requires a three-component controller. The MCC-1 Controller, described in the first edition was therefore redesigned for three-component operation and was considerably simplified because of changes introduced to the calibration procedures. This new controller was also installed at Macquarie Island in October 1984 and will be included in the Mawson installation in 1985.

A third three-component system is currently under construction for the Canberra Magnetic Observatory, where it will be used for training and for long-term assessment. A fourth system for Toolangi is scheduled for construction in 1985.

This second edition of the handbooks contains additional information relating to the Z-component; the description of the setting-up procedures has been summarized and some errors corrected.

Acknowledgements listed in the preface to the first edition are again gratefully made, with the addition of S. Prokin who was involved in mechanical construction.

November 1984

PREFACE TO FIRST EDITION

This Record comprises two equipment handbooks written for two associated instruments designed and constructed within the Engineering Services Branch of BMR: the MPE-1 Photo-electronic Magnetometer and the MCC-1 Magnetometer Controller.

One system, comprising two MPE-1 units and one MCC-1 is to be installed at the Mawson (Antarctica) Magnetic Observatory during 1983. A second system will also operate during 1983 at the Canberra Magnetic Observatory, where long-term performance will be assessed; it will then be installed on Macquarie Island.

The MPE-1 design principles may have other applications --- for example, in measuring the vertical magnetic field in a magnetotelluric system; this is to be investigated.

Contributions to the development of these instruments by the following BMR staff members are gratefully acknowledged:

P. McGregor, of the Observatories Section, requested the instruments and assisted with many helpful discussions. Within the Engineering Services Branch, initially D. Gardner and later G. Black played a major part in construction, testing and debugging; D. Stevens and R. de Graaf designed and fabricated the mechanical components, and R. Gan with K. Mort produced the drawings, printed circuit artwork and parts lists.

April 1983

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GENERAL DESCRIPTION AND PERFORMANCE SPECIFICATIONS

1.1 GENERAL DESCRIPTION

The MPE-1 and MPE-2 variometers measure variations in the horizontal and vertical component respectively of the earth's magnetic field. The MPE-1 sensor is a QHM (Quartz Horizontal Magnetometer); the MPE-2 sensor is a La Cour Z-Balance. An electronic feedback loop backs off the field variations, thus keeping the sensor magnet in a null position.

The position of the sensor mirror is detected optically using a light-emitting diode (LED) light source and a lateral-effect photodiode detector. The amplified detector signal causes a current to flow in a Helmholtz coil around the sensor, thus backing off the field changes. The voltage giving rise to this current is a measure of the field component, and forms the variometer output.

This system has the advantage that QHM magnetometers and La Cour Z-Balances, already owned by BMR and having known histories and characteristics, can continue to be used in data acquisition systems requiring electronic inputs. Also, the disadvantages of photographic recording are eliminated.

A Type 1 control loop is used, which means that there is essentially no error in the null position of the magnet for any steady-state field within the range of the instrument. Electronic compensation, necessary for control loop stability, gives a relatively rapid time response without overshoot, and a frequency response without peaks.

Figure 1.1 is an annotated photograph of the MPE-1, while figures 1.2 and 1.3 depict the MPE-2. Each MPE mounts on an acrylic base plate measuring 600 mm x 300 mm x 20 mm. The electronics assembly, comprising the light source, the detector and a 15 cm x 15 cm printed circuit board, is housed in a diecast box mounted at one end of the base. The sensor and Helmholtz coil system mount at the other end. Adjustments are provided for mechanical and optical alignment.

The QHM is unmodified except for the addition of a biconvex crown glass lens (23 mm diameter, 275 mm focal length) and its retaining ring. Also, a small keeper block is installed in the torsion head to prevent the fibre holder from falling through its clamp when the clamp is loosened to allow the quartz fibre to be torsioned. This operation is necessary to orient the magnet at right angles to the field component being measured.

The essential La Cour sensor components are removed from their original brass housing and fitted in a more compact and lighter acrylic enclosure. The original prism is replaced with a front reflecting mirror approximately 50 mm x 20 mm to obtain greater reflected light on the photodiode. The bimetalic prism mount is replaced with an aluminium support. The lens, mounted in the acrylic housing, has a diameter of 38 mm and a focal length of 275 mm.

The Helmholtz coil system was previously designed, for scale-value and orienting purposes, for La Cour variometers. The system comprises two orthogonal Helmholtz coils (radius 11.2 cm), each rewound with a 12 turns per section. A separate single turn is wound under each of these coils. The one under the feedback coil is used for scale-value (calibration) checks; the other is not used.

The feedback coil for the QHM system has its axis across the MPE-1 base plate, and the axis of the orienting coil is parallel with the long edge of the base plate. For the La Cour system, the axis of the feedback coil is vertical and the axis of the orienting coil is across the MPE-2 base plate.

The MPE-2 is easily converted to an MPE-1 by rotating the Helmholtz coil, replacing the Z-balance with a QHM and performing the appropriate adjustments. Base plates for later units were fabricated with mounting holes for both configurations.

All surfaces likely to give undesirable light reflections are painted matt black.

In a normal observatory installation, two MPE-1 variometers measure orthogonal horizontal field components, and an MPE-2 measures the vertical component. A separate instrument, the MCC-1 Magnetometer Controller, supplies plus and minus 15 volts d.c. (from 240-volt mains or external 24-volt d.c.) to all MPE units, and also provides the necessary orienting current and scale-value current facilities. The MCC-1 is fully described in a separate handbook.

The MPEs were entirely designed and constructed in the Engineering Services Unit of BMR.

1.2 PERFORMANCE SPECIFICATIONS

RANGE

Plus and minus 1 000 nT referred to initial reference field.

OUTPUT

Analogue, 10 mV/nT, bipolar, into a high impedance. Offset is adjustable from -8 volts to +8 volts.

RESOLUTION

Limited by noise level. Better than 0.04 nT has been observed during periods of magnetic and seismic quiet. Basic instrumental noise is not yet determined.

TRANSFER FUNCTION (normalized wrt magnet natural frequency)

CONSTANT	POLES	ZEROS
1 920	-0.52	-0.87
	-2.40 + j2.43	-0.96
	-2.40 - j2.43	
	-8.90	
	-29.8	

FREQUENCY RESPONSE

For a suspended magnet with natural period T seconds, the MPE response with reference to a steady field (0 dB) is: approx. 3.7 dB down at f = 1/T Hz,
" 13.8 " " " f = 5/T "
" 17.2 " " " f = 10/T " .
The ultimate roll-off is -18 dB/octave (equivalent to -60 dB/decade).

STEP RESPONSE

For a suspended magnet with natural period T seconds:

10% to 90% rise-time is 3.2T seconds.
The output is overdamped (no overshoot), and settles to within 1% in 8T seconds.

POWER SUPPLY (for each MPE)

+15 V d.c. at 70 mA (typ.), 176 mA (max.)
-15 V d.c. at 55 mA " , 124 mA "

TEMPERATURE COMPENSATION

Capable of compensating sensor magnet linear co-efficients of up to plus or minus 50 nT per degree.

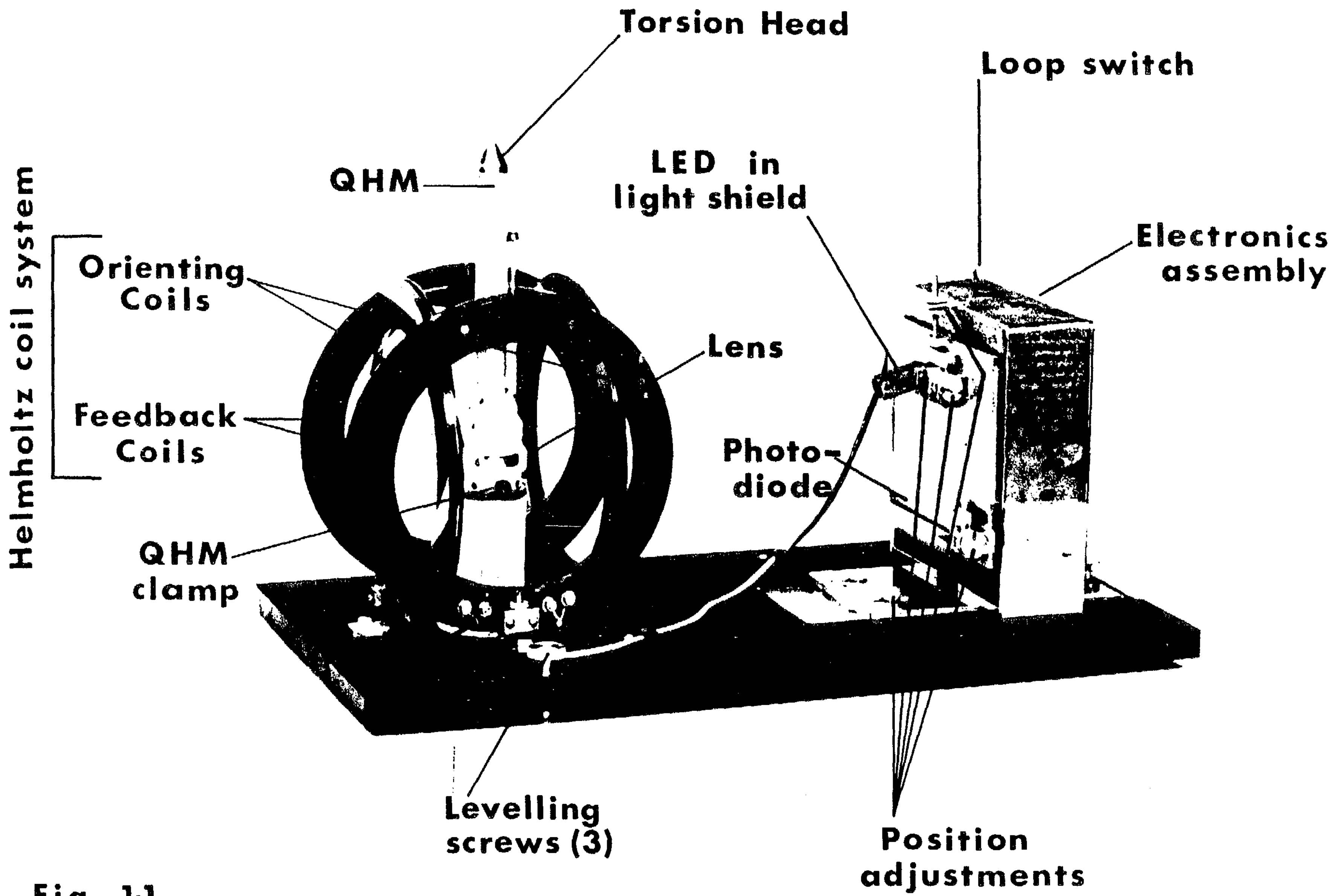
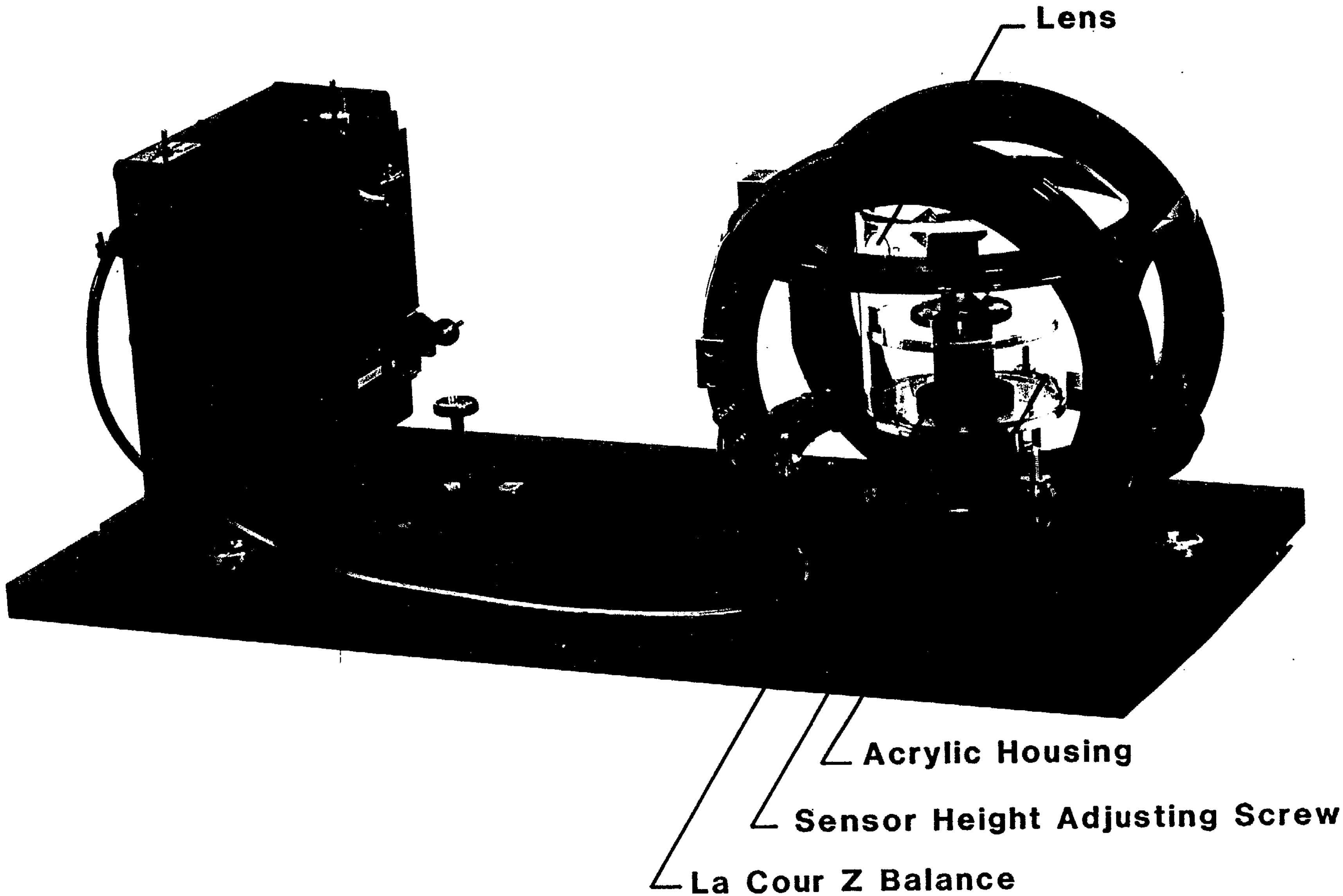


Fig. 1·1

Photograph of MPE-1



Lens
Acrylic Housing
Sensor Height Adjusting Screw
La Cour Z Balance

Fig. 1.2

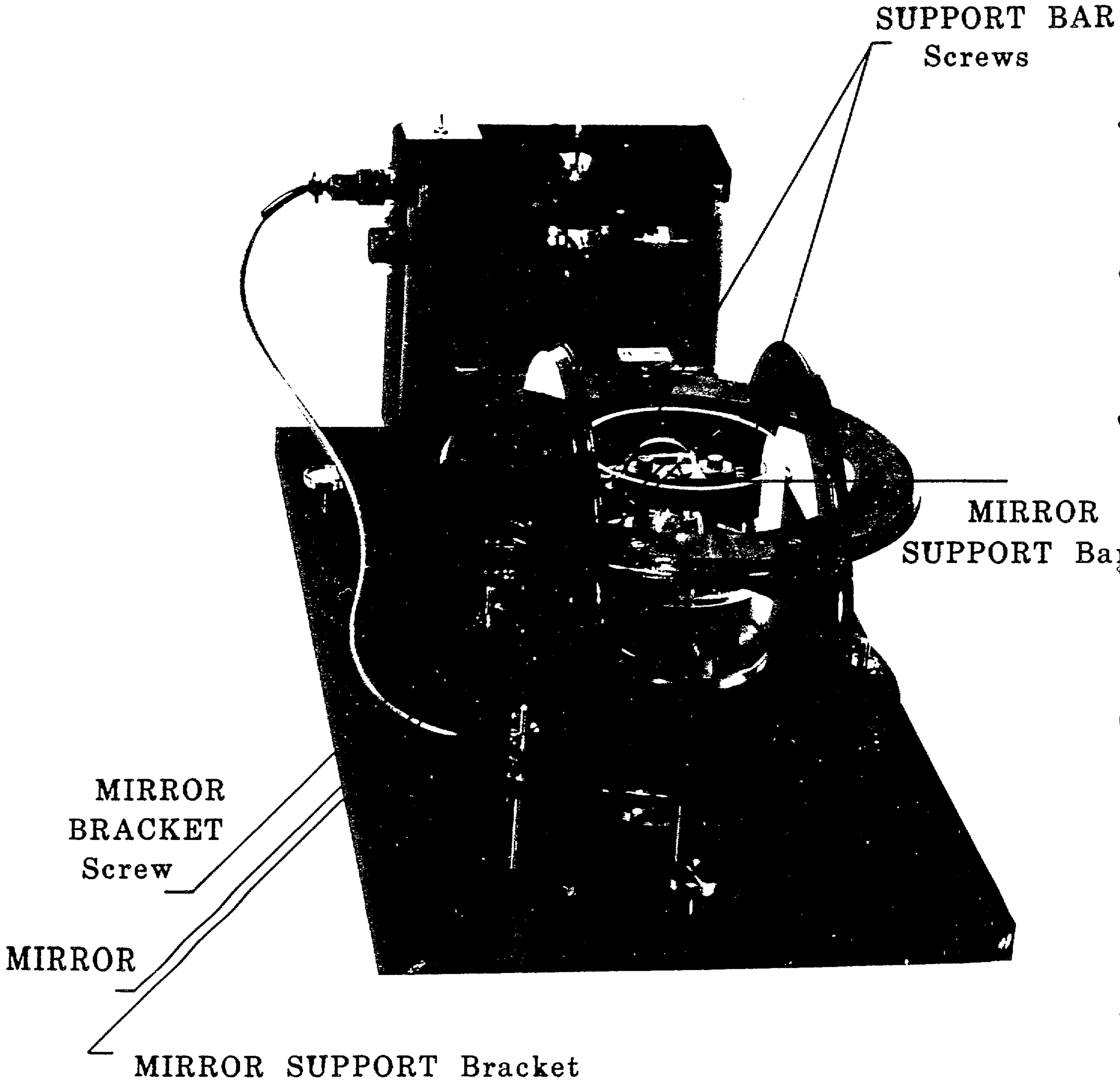

SUPPORT BAR
Screws
MIRROR
SUPPORT Bar
MIRROR
BRACKET
Screw
MIRROR
MIRROR SUPPORT Bracket

Fig. 1.3

2. BLOCK DIAGRAM DESCRIPTION

Figure 2.1 shows the MPE-1 block diagram. The block diagram for the MPE-2 is identical except that a La Cour Z-balance is substituted for the QHM.

Light from the light-emitting diode (LED) is chopped at about 220 Hz. The light passes through the lens on the sensor and is reflected by the sensor mirror back through the lens, coming to a focus on the lateral-effect photodiode which produces a differential current output dependent on the distance of the light spot from the centre of the photodiode. A pair of low-noise transresistance amplifiers with gains of -1 V/uA convert the photodiode currents to voltages.

The position sensitivity of the photodiode depends on the product of the light-spot intensity and the photodiode responsivity. In order to keep this product constant, regardless of component replacement or aging, the transresistance amplifier outputs are summed and half-wave demodulated to give a d.c. signal proportional to the intensity-responsivity product. This signal is summed with a preset voltage reference, the sum forming the input to an integrator which drives the LED. The resulting negative feedback loop ensures that the demodulated d.c. signal remains equal and opposite to the reference voltage, so keeping the intensity-responsivity product constant. Thus the loop-gain of the overall magnetometer feedback loop is independent of the optical devices. The LED drive is chopped at a 220-Hz rate by the chopper oscillator.

A unity-gain differential amplifier subtracts the transresistance amplifier output voltages to give a 220-Hz square-wave signal with sign and magnitude determined by the direction and distance of the light spot from the centre of the photodiode. Subsequent a.c. coupling eliminates the effects of d.c. drift in the high-gain input circuits. The gain of the a.c. amplifier can be set to either 2 or 100 to allow for wide differences in magnet sensitivities. Following the a.c. amplifier, the signal is converted to d.c. by a full-wave synchronous demodulator and is amplified by a d.c. amplifier having adjustable gain. This adjustment, in combination with the a.c. amplifier gain setting, ensures that the desired loop gain is attained irrespective of QHM characteristics. The open-loop gain is set so that a variation of one nanotesla in the field being measured causes a change of thirty-three millivolts in the output of the d.c. amplifier.

For essentially zero steady-state error, the control loop requires an integrator; this follows the d.c. amplifier. Associated with the integrator is a lead-lag compensation network --- one of two needed to combine the desired response characteristics with an adequate stability margin. Both compensation networks are adjustable to allow for differing sensor characteristics.

Analogue output for a chart recorder or data acquisition system is taken from the integrator stage via a unity-gain buffer amplifier. The nominal output sensitivity is 10 mV/nT and the range is plus and minus 1 000 nT. An adjustable voltage is summed into the buffer amplifier so that the output voltage may be offset by up to plus or minus 8 volts. This is for situations in which field variations are markedly asymmetric about the mean value.

The feedback path comprises the second lead-lag compensation network, the Helmholtz-coil driver (nominal transconductance -1 mA/V), and the Helmholtz coil, which produces the feedback field to null the measured field and has a coil constant of about 96 nT/mA. The combined response of the Helmholtz coil and its driver can be set, by an adjustment in the coil driver, to be 100 nT/V, thus setting the output sensitivity to 10 mV/nT.

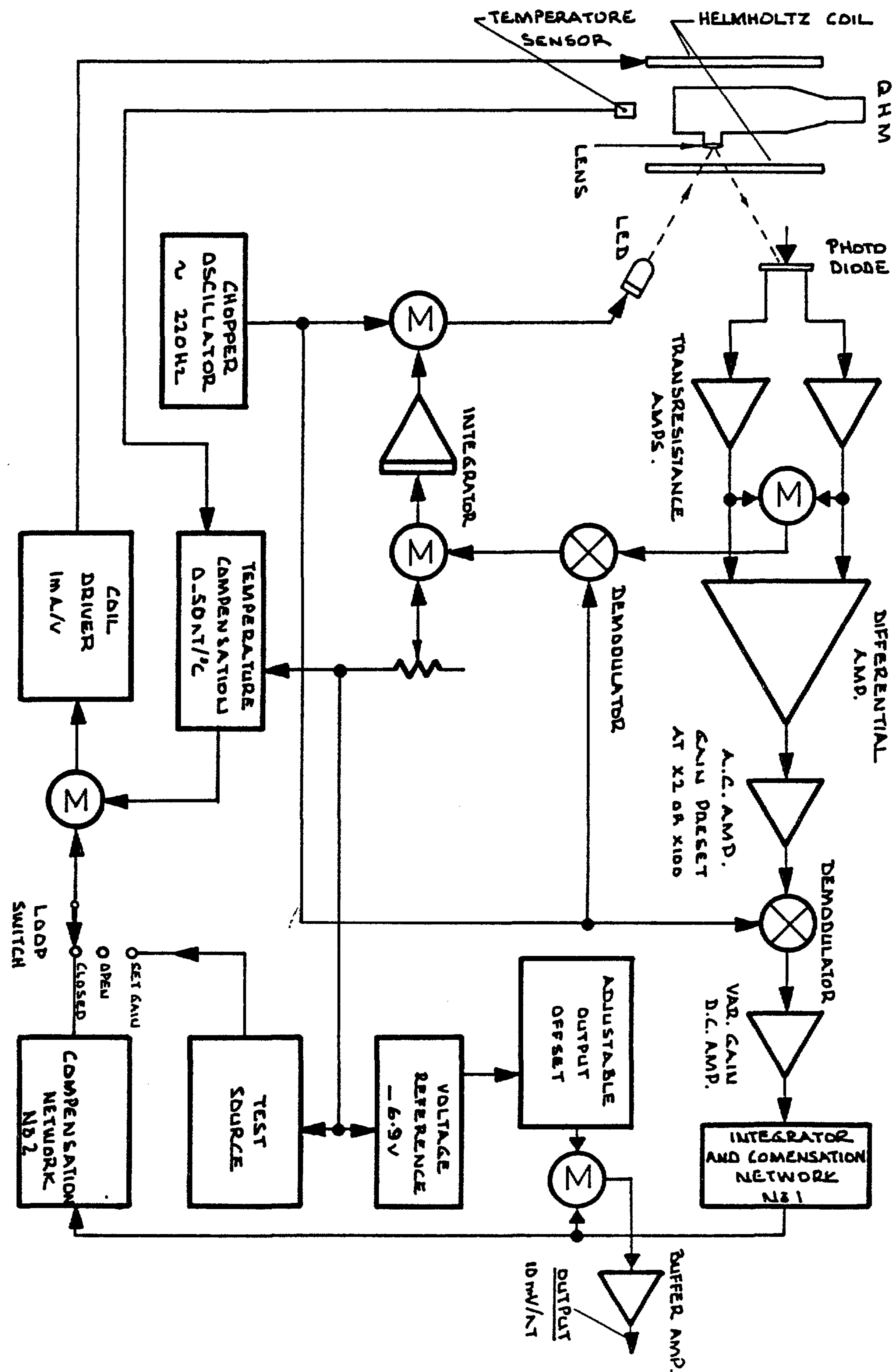
A three-position loop switch, between the second compensation network and the coil driver, is used in the setting-up procedure. Normally the loop is closed, but the loop switch may be used to open the loop or to connect a test source to the opened loop for initial coil-driver and loop-gain adjustments.

A semiconductor temperature sensor is mounted at the field sensor. The temperature sensor voltage is linearly related to absolute temperature and produces a corresponding current which is summed into the coil driver input. This compensating current is adjustable to cover the range of plus and minus 50 nT per degree.

The 220-Hz (nominal) chopper oscillator supplies the reference signal for both demodulators, and also the signal which chops the LED drive current.

A -6.9 volt reference supplies the optical feedback, the output offset, the test source, and the temperature compensation circuits.

FIG. 2.1 MPE-1 BLOCK DIAGRAM



Bureau of Mineral Resources, Geology and Geophysics, P.O. Box 378, Canberra City, A.C.T. 2601	Drawing No. M 8	Issue	Title:
	Sheet No. 4	2	PHOTO. ELEC. MAG.
	Drawn [signature] Date 21/11/85		BLOCK DIAGRAM

3. OPERATION

The MPE-1 and MPE-2 are intended to be used with the MCC-1 Controller, which has provision for three-component operation, i.e. two MPE-1 units each measuring a specified horizontal component of the earth's magnetic field, and one MPE-2 unit measuring the vertical component.

Normal practice is to set up the MPE-1 and MPE-2 units in a magnetic observatory, and the MCC-1, together with a local chart recorder if required, in an anteroom sufficiently far from the magnetometers to avoid magnetic interference. (A remote recorder may also be connected via the MCC-1).

Special requirements for the MPEs are a darkened room and a pier or support free from vibration --- the QHM suspension acts as a pendulum if disturbed mechanically, and causes the output to be modulated. See Section 4.2 for a cautionary note against locating MPE-1 units where they can interact magnetically or optically.

Section 4 describes in detail, and Section 5 describes in summary, the setting-up procedure for the MPEs. Once this has been done, operation is straightforward. The following precautions should be observed:

1. Do not allow magnetic materials near the MPEs; they could cause the QHM magnet to flip to the wrong orientation (see Section 4.5), and physical movement or temperature effects could produce spurious field values.

2. If, for any reason, the light spot is deflected off the active surface of the photodiode, it is unlikely to return to the null position. Therefore, large rapid field changes, or momentary power failures, which could cause this, should be guarded against. To recover, open the feedback loop and allow the magnet oscillations to decay before closing the loop; if the magnet has flipped, proceed as in Section 4.5.

Small oscillations on the output are usually caused by mechanical or seismic disturbances. Other possibilities include feedback from the local recorder pen motor, and beats caused by the light from one MPE being detected by the photodiode in another MPE (it is unlikely that the chopper frequencies in the two units will be the same, so a beat will occur at a frequency equal to their difference).

The MCC-1 provides scale-value pulses. Regular inspection of the amplitude and rise-time of the pulses at the MPEs' outputs will reveal performance abnormalities.

The electronic control loop does not contribute a significant temperature coefficient compared with the known coefficients of sensor magnets. Electronic temperature compensation may be set up (Section 4.18), but if it is desired to reduce temperature variations, a non-magnetic thermally insulated cover should be carefully placed over each MPE unit. This would also serve as a light shield. The inside of the cover must have a matt black or otherwise non-reflective surface.

4. DETAILED SETTING-UP PROCEDURE

This description is comprehensive in that it applies to the initial installation of a newly constructed system. For a previously aligned system some steps are obviously unnecessary and may therefore be omitted; however, the sequence of the remaining steps should conform with the sequence given in this description. Unless indicated otherwise, the setting-up may be performed in moderate ambient light. For a multi-component system it may be more practical to set up all components together than to set up one component completely and then to repeat the whole procedure for the subsequent components. Section 5 summarizes these setting-up instructions.

4.1 EQUIPMENT REQUIRED

Controller, BMR Type MCC-1 (part of installation)
CRO with two-channel summing capability
Digital multimeter (DMM)
Bubble level, circular
Tommy-bar, non-magnetic
Measuring scale, non-magnetic
White card with vertical black line for observing light spot
Screwdrivers, various sizes
Stopwatch
Compass
Heater and, if possible, portable variometer for temperature compensation.
Try-square
Spare circuit board
Calculator

4.2 MECHANICAL ALIGNMENT

CAUTION

When choosing locations for the MPE-1/MPE-2 units in a multi-component system, ensure that:

1. The units are spaced sufficiently to reduce mutual magnetic interference, from magnets or from feedback Helmholtz coils, to 1 nT or less. One metre separation is probably adequate, but this should be checked at initial installation.

2. The units are either sited or screened to prevent the light source of one from illuminating the photodiode of the other, whether directly or by reflection.

Place the MPEs on their respective piers in the following orientations:

X unit (magnet E-W) with the Helmholtz coils at the eastern end if D is easterly
or
western end if D is westerly. Refer to Fig 4.1.

Y unit (magnet N-S) with the Helmholtz coils at the northern end. Refer to Fig 4.2.

Z unit (magnet N-S, N pole north) with the Helmholtz coil at the eastern (or western) end. (Note: the Z unit should be aligned so that the magnet lies in the magnetic meridian +/- 10 degrees).

Align the ORIENT coils within 0.25 deg:

X unit NORTH-SOUTH (i.e. coil axis EAST-WEST)

Y unit EAST-WEST (i.e. coil axis NORTH-SOUTH)

Z unit VERTICAL (i.e. coil axis HORIZONTAL)

Using a circular bubble level, ensure that the base is level. Check this at several places around the coil system and estimate an average level position if there are discrepancies caused by the base sagging or warping.

Check, and adjust if necessary, the position of the Helmholtz coils to meet the following requirements:

1. QHM systems (X and Y)

The coils should be vertical with respect to the base and should be adjusted by means of a try-square if necessary. The exact height is not critical and, as a guide, about the middle of the adjustment range is suitable.

2. LA COUR systems (Z)

The orient coils should be vertical with respect to the base, and the scale value coils should be horizontal. Adjustments can be made using a try-square or a bubble level. For maximum reflected light, the Helmoltz coils should be adjusted to be as low as possible on the base.

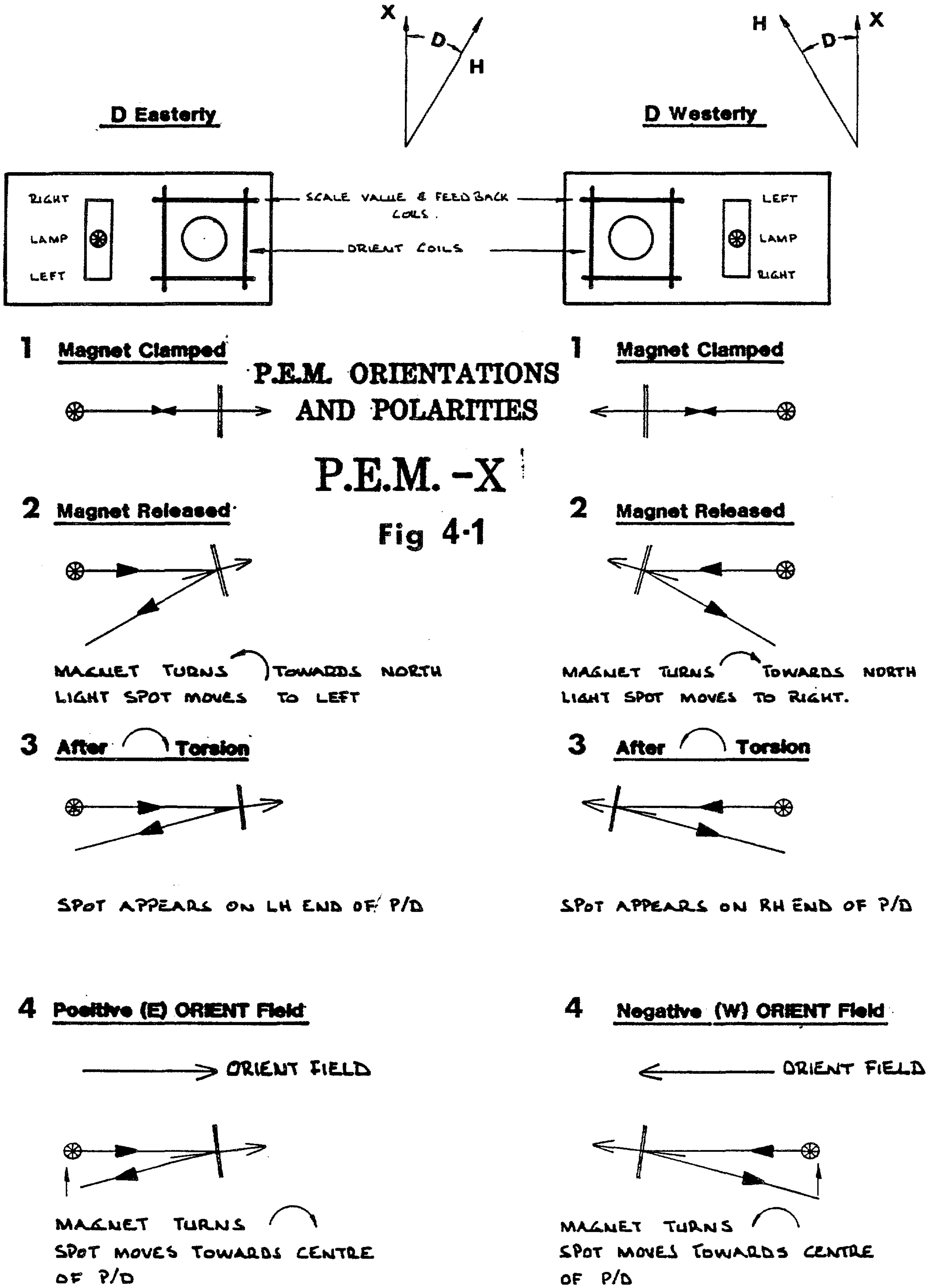


Fig 4·1

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	Sheet No. 5a	1	P.E.M. ORIENTATIONS & POLARITIES
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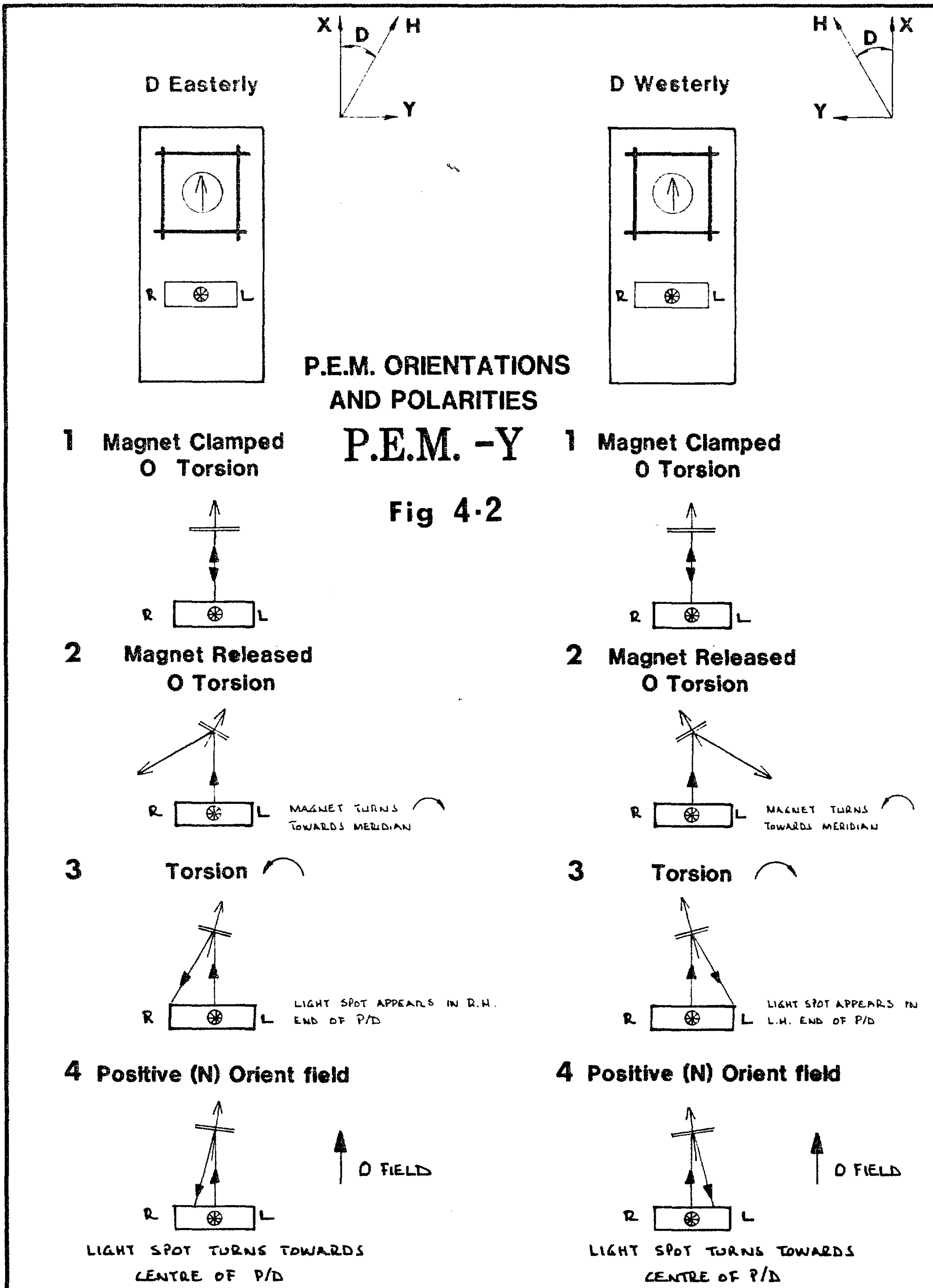

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To assist with system alignment, the scale-value coils on a QHM system are parallel to the longer edge of the base, i.e. their axes are at right angles to this edge. Nominal alignment tolerance is 0.25 degree; this should be checked when initially setting up.

4.3 SENSOR HEIGHT

The sensors should be transported in their own transit boxes. To mount them, first undo the single set-screw in the side of the polycarbonate mounting pillar on the MPE base and remove the sliding section.

1. QHM

   Ensure that the QHM is clamped and remove it from its transit box. When mounted, the blackened lens retaining ring must face the electronics assembly. Fasten the QHM to the sliding section of the mounting pillar with two screws, working from the underside. Replace the assembly on the fixed part of the mount and tighten the set-screw.

   Unclamp the QHM. With a measuring scale, check that the QHM magnet is vertically centered in the coil system. If adjustment is necessary, clamp the QHM and loosen the set-screw. Raise or lower the QHM by the necessary amount and tighten the set-screw.

2. LA COUR Z-BALANCE

   When assembled, the single locating pin in the upper edge of the lower housing of the La Cour must face the electronics assembly. Attach the housing to the sliding section with two screws, working from the underside. Replace the assembly on the fixed part of the mount and tighten the set-screw.

   Place the magnet, with its north pole facing north, on the lifters and gently lower the magnet so that its knife-edges rest on the agate surface. With a measuring scale, check that the La Cour magnet is vertically centered in the coil system. If adjustment is necessary, raise the magnet with the lifter and loosen the set-screw. Raise or lower the housing by the necessary amount and tighten the set-screw.

4.4 OPTICS --- INITIAL SETTING

Adjust the lateral positions of the LED and the photodiode for symmetry with respect to the sensor.

Check that the four nylon screws which clamp the electronics assembly to the base are located in the rear-most set of threaded holes in the base. Loosen these screws and move the entire assembly so that the screws are central in their adjustment slots. Re-tighten the screws.

1. QHM

   Unclamp the QHM and measure, from the base, the height of the horizontal centre-line through the QHM mirror. Clamp the QHM. Adjust the vertical position of the plate holding the LED and the photodiode so that the LED emitter and the active surface of the photodiode are equidistant above and below the mirror height. (Note that the LED and photodiode are nominally 100 mm apart.)

2. LA COUR Z-BALANCE

   To obtain maximum reflected light, the plate holding the LED and the photodiode should be adjusted to about 5 mm below its highest position.

4.5 MAGNET ALIGNMENT

1. QHM

   Unscrew the conical brass cap at the top of the QHM. Use a fine tommy-bar to loosen the two clamp screws in the torsion head. (Above the clamp is a keeper block which prevents the fibre-holder from falling through the clamp. DO NOT LOOSEN THE SCREWS IN THE KEEPER BLOCK.) Unclamp the QHM magnet. Torsion is adjusted by rotating the spindle of the fibre-holder with the tommy-bar so that the mirror assumes its correct rest position with its singly reflective side facing the electronics assembly.

   NOTE: Special care is needed to avoid large magnet swings when adjusting in the X orientation if X is very close to H (total horizontal field), i.e. when the declination angle is small. Under these conditions, the magnet may swing through H to a point of instability and suddenly flip through a large angle. If this occurs, detorsion the fibre and start again. (To detorsion the fibre, remove the set-screw from the QHM mounting pillar to allow rotation of the QHM without disturbing the alignment of the MPE-1.)

X UNIT

Unclamp the magnet. It will turn towards the magnetic meridian:

ANTI-CLOCKWISE if D is EASTERLY,
CLOCKWISE if D is WESTERLY.

D EASTERLY
Apply torsion clockwise (to turn the magnet towards the E-W direction) until the reflecting surface of the mirror is transverse to the MPE-1 base.

D WESTERLY
Apply torsion anticlockwise (to turn the magnet towards the E-W direction) until the reflecting surface of the mirror is transverse to the MPE-1 base.

Y UNIT

Unclamp the magnet. It will turn towards the magnetic meridian:

CLOCKWISE if D is EASTERLY,
ANTI-CLOCKWISE if D is WESTERLY.

D EASTERLY
Apply torsion anti-clockwise (to turn the magnet towards the true (N-S) meridian) until the reflecting surface of the mirror is transverse to the MPE-1 base.

D WESTERLY
Apply torsion clockwise (to turn the magnet towards the true (N-S) meridian) until the reflecting surface of the mirror is transverse to the MPE-1 base.

2. LA COUR Z-BALANCE

It is assumed that the magnet/support system has already been balanced approximately for the ambient Z field. If not, the magnet should be ground until it balances approximately horizontally.

4.6 OPTICS --- COARSE ADJUSTMENT

Connect the MPE to the appropriate channel (X, Y or Z) of the MCC-1 Controller via the cables supplied, and apply power. If less than three MPEs are being used, ensure that dummy plugs are fitted to the unused sockets of the MCC-1.

Ensure that the MPE loop switch is in the OPEN (central) position.

Remove the eight nylon screws retaining the rear cover of the electronics assembly and remove the cover. Turn the optical sensitivity potentiometer, R49, fully clockwise to ensure maximum light intensity.

Using a white card to observe the position of the light beam at the sensor, adjust both the lateral position and the tilt angle of the LED to centre the beam on the QHM or La Cour lens. Clamp the lateral adjustment (on early X and Y units only). If excessive lateral movement (greater than 1 cm) of the LED is necessary, the cause is probably an offset between the mechanical and optical axes of the LED. The effect of such an offset should be removed by rotating the LED in its holder until the offset is confined to the vertical plane. To do this proceed as follows:

> Turn the power off. With the rear cover of the electronics assembly removed, undo the three aluminium screws holding the printed circuit board; allow the board to hang freely. Remove the two screws from the flanges of the LED assembly mounting bracket and pull the assembly forward, easing the shielded lead through the hole in the front plate, so that the rear of the LED is accessible. Working inside the brass light shield, loosen the two small screws which fasten the LED nylon clamp ring. The LED may now be rotated and checked. Repeat until a satisfactory position is obtained. Restore the electronics assembly and set the lateral adjustment and tilt angle of the LED. Clamp the lateral adjustment.

4.7 FINAL ORIENTATION

Remove all magnetic objects from the vicinity.

NOTE. Orientation should only be adjusted when the magnetic field is undisturbed.

To obtain an ORIENT field, switch the MCC-1 Controller to ORIENT and select X, Y or Z channel as appropriate. Placing the MCC-1 switch labelled '+', 'OFF', '-' in the '+' or '-' position causes a direct current of up to 30 mA, set by the ORIENT CURRENT potentiometer, to flow in the orienting Helmholtz coil (which is orthogonal to the feedback coil). The maximum orienting field available is about 2 500 nT.

If, in the following tests, the orient field is found to be reversed, disconnect the power from the MCC-1 controller and reverse the connections to the ORIENT coil at the Helmholtz coil of the component affected.

1. X UNIT (QHM)

D EASTERLY
Trim the fibre torsion until the reflected light spot appears on the left hand end of the photodiode.

D WESTERLY
Trim the fibre torsion until the reflected light spot appears on the right hand end of the photodiode.

Apply a +ve ORIENT current and observe the spot. If it deflects to the

1. RIGHT, the field is to the east and CORRECT.

2. LEFT, the field is to the west and REVERSED.

As the final orientation is adjusted, the light spot will move towards the centre of the photodiode.

The following current polarities must be used:

D Easterly -- +ve ORIENT current.
D Westerly -- -ve ORIENT current.

Using the above orienting current polarity, continue the sequence: current on, note deflection direction, current off, adjust the torsion so the light spot moves in this direction. The deflection produced by the orienting field will lessen with each adjustment until, for the correct adjustment, no movement will occur. This should be checked with the orienting current at maximum. If the adjustment is taken too far, the adjustment direction will change but the same current polarity must be used.

Clamp the torsion head and replace the conical cap.

Re-adjust the photodiode lateral position to centre the light spot.

2. Y UNIT (QHM)

D EASTERLY
Trim the fibre torsion until the reflected light spot appears on the right hand end of the photodiode.

Apply a +ve ORIENT current and observe the spot. If it deflects to the

1. LEFT, the field is to the north and CORRECT.

2. RIGHT, the field is to the south and REVERSED.

D WESTERLY
Trim the fibre torsion until the reflected light spot appears on the left hand end of the photodiode.

Apply a +ve ORIENT current and observe the spot. If it deflects to the

1. RIGHT, the field is to the north and CORRECT.

2. LEFT, the field is to the south and REVERSED.

As the final orientation is adjusted, the light spot will move towards the centre of the photodiode.

Using a +ve orienting current, continue the sequence: current on, note deflection direction, current off, adjust the torsion so the light spot moves in this direction. The deflection produced by the orienting field will lessen with each adjustment until, for the correct adjustment, no movement will occur. This should be checked with the orienting current at maximum. If the adjustment is taken too far, the adjustment direction will change but the same current polarity must be used.

Clamp the torsion head and replace the conical cap.

Re-adjust the photodiode lateral position to centre the light spot.

3. Z UNIT (LA COUR)

Remove the upper chamber of the La Cour housing. With a compass, check that the North seeking end of the magnet is pointing north. (The south seeking end of a compass needle will be attracted by the North seeking end of the LA COUR magnet)

By means of the lifter, lower the magnet onto its agates.

Replace the upper chamber of the La Cour housing and remove the lid. Loosen the two large screws which secure the mirror support bar to the vertical posts and adjust the mirror support bar to its highest position; tighten the screws. Loosen the single small screw which clamps the mirror bracket and adjust the angle and height of the mirror to give a light spot appearing at the level of the photodiode. Maximum reflected light will occur when the mirror is at the highest position posible in the bracket. Tighten the screw to clamp the mirror bracket.

NOTE. THE MIRROR HAS ITS REFLECTIVE SURFACE ON THE FRONT AND CAN BE VERY EASILY DAMAGED IF HANDLED ROUGHLY ON THAT SURFACE.

Rotate the mirror mounting bracket by loosening the three screws and moving the bracket by hand to position the spot near the centre of the photodiode. (If this is not possible the magnet may not be balanced well enough; it would then be necessary to grind the magnet further to acheive a better balance.) Tighten the screws to clamp the bracket.

Apply an external +ve field to the magnet by placing another magnet horizontally, with its N pole pointing north, in the meridian to the south of the Z magnet, and at the same height. Observe the deflection of the light spot.

> NOTE. No deflection will occur if the Z magnet is exactly horizontal. In which case it will be necessary to apply an external field to tilt the magnet before performing the above test. This may be achieved by positioning a small magnetic object near the base of the LA COUR housing so as to tilt the magnet.

Apply a +ve ORIENT current and obseve the deflection of the light spot with respect to the deflection caused by the external magnet.

If the deflection is:

SAME, the field is Northerly and is CORRECT.
REVERSED, the field is Southerly and is REVERSED.

This completes the La Cour orientation. Ensure that all clamps are tight and replace the housing lid.

4.8 FOCUSING

With the QHM unclamped (or the Z magnet on its agates) and the reflected light spot observable on the white card held hard against the photodiode, loosen the four nylon screws which fasten the electronics assembly to the base. Move the assembly longitudinally to obtain the best focus. Tighten the screws. Recheck the tilt angle of the LED for maximum illumination on the sensor lens and, removing the white card, adjust the vertical height of the front plate of the electronics assembly so that the light spot falls on the active surface of the photodiode. (The spot may be seen in moderate ambient light when viewed through the Helmholtz coil looking from behind the sensor.)

4.9 LOOP SWITCH FUNCTIONS

The loop swich functions must be understood for making the electronic adjustments detailed in the following sections. The loop switch is a three-position toggle switch mounted on top of the electronics assembly. The positions and functions are:

1. CLOSED The switch actuator is towards the sensor. This is the normal operating position with the feedback loop closed. This position is not used for most of the setting-up procedure.

2. OPEN The switch actuator is central. The control loop is disabled, and the output is a low-gain representation of normal sensor behaviour. Most, but not all, of the setting-up is done in this mode.

3. SET GAIN The switch actuator points away from the sensor. In this position, also, the loop is open, and a current step is applied to the Helmholtz coil for gain setting and approximate calibration.

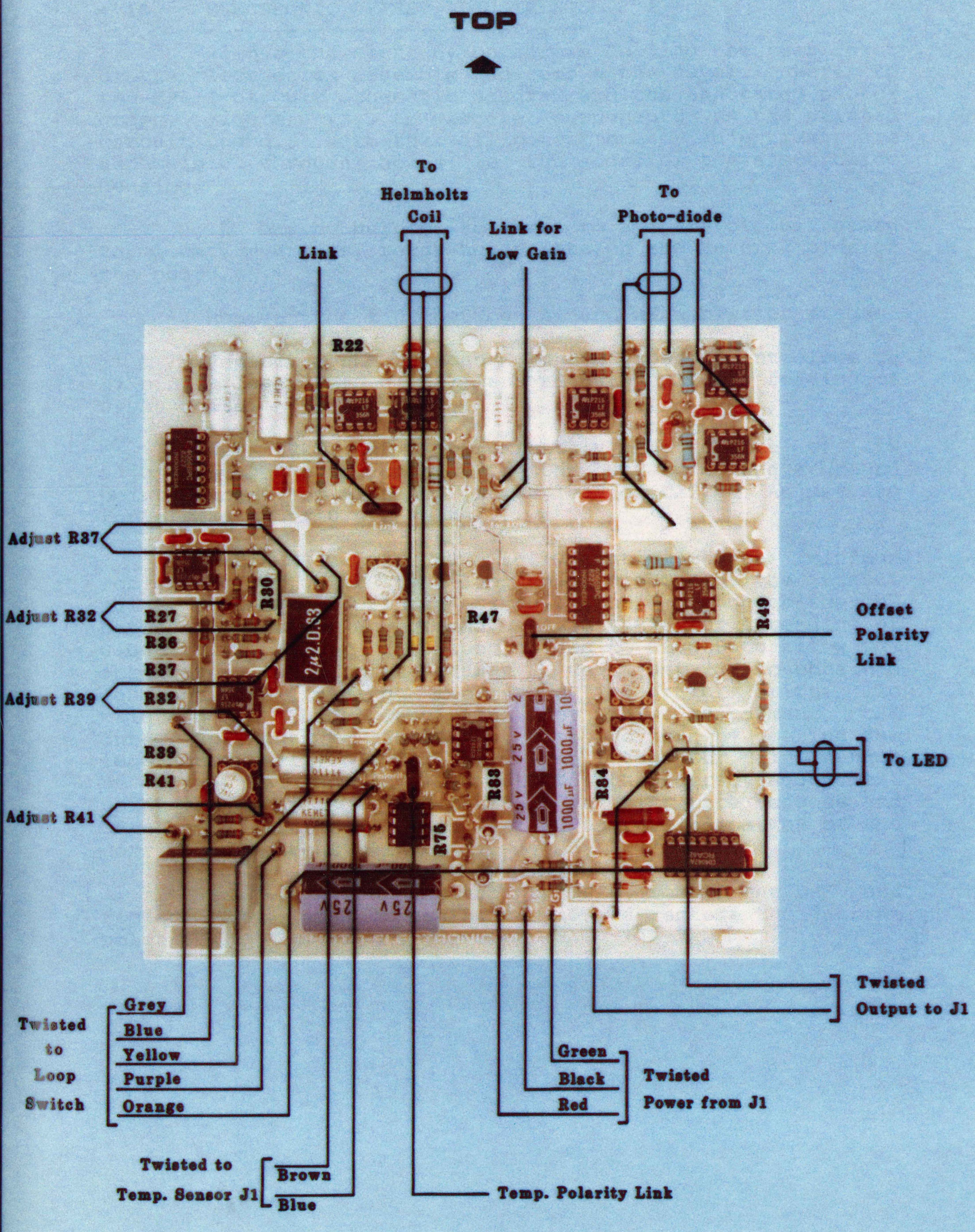
TOP
To
Helmholtz
Coil
Link
Link for
Low Gain
To
Photo-diode
R22
Adjust R37
R30
Adjust R32
R27
R36
R37
Adjust R39
R32
R39
R41
Adjust R41
R47
R49
Offset
Polarity
Link
To LED
R83
R84
R75
Twisted
Output to J1
Twisted
to
Loop
Switch
Grey
Blue
Yellow
Purple
Orange
Green
Black
Red
Twisted
Power from J1
Twisted to
Temp. Sensor J1
Brown
Blue
Temp. Polarity Link

Fig. 4.3

M8/1

4.10 ELECTRONIC OFFSET ADJUSTMENTS

Remove the eight nylon screws holding the rear cover of the electronics assembly and remove the cover. Refer to the MPE-1 circuit schematic diagram and the annotated photograph, Figure 4.3, to locate components on the printed circuit board. Note that all potentiometer adjustments are accessible through holes in the sides of the electronics housing.

It may be helpful to refer to a spare circuit board to locate various reference points on the reverse side of the board.

Remove the link between A4 and A5 amplifier stages.

Connect a DMM between M3 and a ground point close to A7 pin 3 (lower lead of C17) and adjust R22 for a reading of 0.000 volts.

Set R27 at approximately the centre of its adjustment range and connect the DMM between M4 and a ground point close to A8 pin 3 (lower lead of C17). Adjust R30 for a reading of 0.000 volts.

Turn R32 and R37 fully anticlockwise (minimum resistance). With the loop open, disconnect the jack at point F on the printed circuit board; connect the DMM between point F and ground. Adjust R36 for a reading of 0.000 volts. Set the loop switch to CLOSED to allow the integrator capacitor to charge. Re-adjust R36 to obtain a constant DMM reading, i.e. zero integrator drift. To maintain a high resolution for this adjustment, the integrator output can be kept close to zero by opening the loop momentarily. Generally, the integrator drift cannot be eliminated completely, but, as the correct adjustment point is approached and passed, the drift rate reduces and changes direction. This is a useful indication of the correct adjustment point.

Set the loop switch to OPEN, remove the DMM, and replace the link between A4 and A5 and restore the jack at point F.

4.11 INITIAL CALIBRATION

The purpose of this adjustment is to set the combined response of the Helmholtz coil and its driving amplifier to 100 nT/V. For a Helmholtz-coil constant Kh nT/mA, the magnitude of the transconductance of the coil driver, |G|, must be 100/(Kh) mA/V. The theoretical coil constant for a Helmholtz coil is:

Kh(th) = {64.pi/(sqrt5)}.(n/r) nT/mA

where n is the number of turns on each coil section and r is the coil radius (and coil separation) in cm. For the coils used, n=12 and r is 11.2 cm. Thus,

Kh(th) = 96.34 nT/mA, and

|G| = 1.038 mA/V

With a DMM, measure the voltage, Vc, at M5 (the input to the coil driver) when the loop switch is in the SET GAIN position. Return the loop switch to OPEN. Disconnect one lead to the feedback Helmholtz coil by unplugging the red lead at the circuit board and insert the DMM set to measure current. The current should be approximately zero. Switch back to SET GAIN and adjust R47 for a current change of:

1.038*Vc mA.

The nominal value of this current change is 1.57 mA, but component tolerances will cause variations from unit to unit. Return to loop switch to OPEN and restore the Helmholtz coil lead to its normal position.

4.12 COMPENSATION NETWORKS

Measurement of the natural period of the sensor is needed for setting-up the compensation networks. The natural period of a given QHM/La Cour varies inversely as the square root of the field component along the magnet axis; it must therefore be determined for each location and orientation.

Observe the light spot on a white card placed in front of the photodiode. Momentarily move the loop switch to SET GAIN, then return it to OPEN. The resulting field impulse will cause a damped natural oscillation of the magnet. It may be necessary to cycle the loop switch as mentioned several times to increase the amplitude of the oscillation. Use a stopwatch to time ten full periods and note the average period, Tav.

The four resistance networks, R31 + R32, R33 + R37, R38 + R39 and R40 + R41, (measure between test points M4 to M12, M12 to M10, M11 to M9 and M9 to M8 respectively) must each be adjusted to have a total resistance given by:

$$Rcomp = 72.34(Tav) \text{ kohms}$$

To make the necessary resistance measurements, turn off the power to the MPE, then, for each network, connect a DMM, set to measure resistance, to the relevant points shown on the photograph of the printed circuit board (Figure 4.3). Although 1% accuracy is easily obtained, matching the four networks is more important than obtaining absolute accuracy.

Disconnect the DMM before restoring the power.

4.13 OPTICAL SENSITIVITY

Darken the room. In particular, a.c. operated lighting should be eliminated.

Connect one channel of a two-channel CRO to M6 and the other channel to M7. Keep both channels at the same sensitivity.

The signal amplitudes on the CRO screen may be unsteady for some time because of pendulum-like oscillations of the QHM suspension induced by mechanical disturbances --- even loop-switch operation will cause them. Time must be allowed for these to decay sufficiently to obtain a reliable estimate of average signal amplitude. If the light spot is approximately central on the photodiode, both channels will display about the same peak-to-peak amplitudes for the 220-Hz signals at the outputs of A1 and A2. Set the CRO to sum both channels. The peak-to-peak amplitude of the sum is proportional both to the light intensity and to the photodiode responsivity.

Turn R49 fully clockwise (if not done previously at Section 4.6). This gives maximum LED brightness and forces the optical control loop outside its control range. Allow any signal perturbations to decay, then finely adjust the vertical height of the front plate of the electronics assembly and the angle of the LED for maximum peak-to-peak signal amplitude (1.4 volts p-p should be acheivable). This ensures that the light spot is vertically centred on the active surface of the photodiode.

Allow the signal to settle down, then back off R49 until the signal amplitude is 800 mV peak-to-peak. Disconnect the CRO.

4.14 A.C. GAIN

With the loop switch OPEN, adjust the lateral position of the photodiode so that the light spot is central as indicated by minimum 220-Hz signal on a CRO connected to M2.

Remove the low-gain strap if present and connect the CRO to M13.

Move the loop switch to SET GAIN, if the peak voltage at M13 exceeds 10 volts when this step is applied, install the low-gain strap. Restore the loop switch to OPEN.

4.15 FEEDBACK AND OUTPUT POLARITIES

X unit

Facing the photodiode, observe the direction in which the average position of the light spot moves when the loop switch setting is changed from OPEN to SET GAIN. Since the X field (the field toward the north) should be reduced by the negative input to the coil driver, this movement should be:

To the right, for D Easterly.

To the left, for D Westerly.

If the movement is to the incorrect, reverse the connections to the feedback coil at the printed circuit board.

Y unit

Facing the photodiode, observe the direction in which the average position of the light spot moves when the loop switch setting is changed from OPEN to SET GAIN. Since the Y field (the field toward the east) should be reduced by the negative input to the coil driver, this movement should be:

To the left, for D Easterly.

To the right, for D Westerly.

If the movement is to the incorrect, reverse the connections to the feedback coil at the printed circuit board.

Z unit

Observe the movement of the light spot when the loop switch is moved from OPEN to SET GAIN. For the Z field the motion should be to the left. If the movement is to the right, reverse the connections to the feedback coil at the printed circuit board.

With the room darkened, and with the loop switch at OPEN, observe the waveform at M4 with a CRO set to measure d.c. volts. The waveform will appear as a baseline with spikes at the chopper frequency. If the average level of the baseline is more than about one volt away from zero, bring it to zero by adjusting the photodiode lateral position. Wait until the resulting mechanical disturbance has decayed sufficiently to allow a reliable reading of the baseline average voltage.

Next, observe the average d.c. voltage level shift at M4 when the loop switch setting is changed from OPEN to SET GAIN. The level shift should be in a positive direction for all components; if it is not, reverse the connections to the photodiode (at points 'a' and 'b' on the schematic). Note that all connections to the printed circuit board are made via lead-mounted push-on 1-mm cage jacks, so reversing the photodiode is simply a matter of reversing two of these connections located at the top right of the board (see Figure 4.3).

The resulting configuration ensures that the feedback will be negative, and that the output will increase positively for a magnetic field increase to the north, east or downwards for the X, Y, or Z component respectively.

4.16 LOOP GAIN

With the room darkened, and with the loop switch at OPEN, observe the waveform at M4 with a CRO set to measure d.c. volts. The waveform will appear as a baseline with spikes at the chopper frequency. If the average level of the baseline is more than about one volt away from zero, bring it to zero by adjusting the photodiode lateral position. Wait until the resulting mechanical disturbance has decayed sufficiently to allow a reliable reading of the baseline average voltage.

Change the loop switch setting to SET GAIN. The baseline will oscillate about a new average level. Again, some delay may occur before this new level can be measured reliably.

Adjust R27 so that, when the loop switch setting is changed from OPEN to SET GAIN, the change in average d.c. voltage at M4 is 5.0 volts. (This is approximately equivalent to 33 mV/nT.)

To confirm that the feedback polarity is correct, switch the feedback loop to CLOSED. The voltage at M4 should rapidly go to zero (the chopper signal will be evident on the waveform) and the normal oscillations caused by magnet rotation should be damped out immediately. (There may be some secondary oscillations caused by the magnet-mirror system swinging as a pendulum.) Positive feedback would produce increasing oscillations of the magnet.

Disconnect the CRO and replace the rear cover on the electronics assembly.

4.17 ESTABLISHING THE REFERENCE OUTPUT

Remove all magnetic material from the vicinity and ensure that the MPE system is still correctly oriented physically. Keep the room darkened.

Set up the chart recorder at a sufficient distance to avoid magnetic interference. Zero the recorder before connecting the MPE output. A full-scale sensitivity of 10 volts corresponds to 1 000 nT, or plus and minus 500 nT with a centre zero.

With an assistant to observe the recorder (or otherwise), and with the loop switch at CLOSED, adjust the lateral position of the photodiode for zero recorder pen deflection. Clamp this adjustment.

4.18 TEMPERAURE COMPENSATION

Ideally, this adjustment would be done on a magnetically quiet day so that there would be no field change, or a predictable small field change, throughout the adjustment. If this is not possible, the adjustment may have to be repeated several times. Better still, the field could be monitored by a portable variometer and any change between the start and finish of the adjustment allowed for.

If temperature compensation is not required, connect R74 to ground at the hard-wired link.

Adjust R83 for 0.00 volts measured with a DVM at J1 pin H. The temperature at which this is done becomes the reference temperature for the adjustment and should be the normal room temperature at which the MPE operates.

Carefully and evenly heat the MPE unit until its temperature stabilizes at a few degrees above reference. This may be done by warming the surroundng air with an electric hair dryer, for example. The heating operation would be easier and quicker if the MPE is fitted with an insulating cover. As the magnet heats up, there will be an output change produced by its temperature coefficient. Allow this change to stabilize. Turn off and remove the heater. Link R74 to the + polarity pin and adjust R75 to exactly cancel the output change. If the polarity of the cancelling field is incorrect, link R74 to the - polarity pin. Allow for any field change observed on the monitoring variometer.

Repeat this adjustment until there is no change in output when the unit is heated and the temperature stabilizes.

DO NOT SUBJECT THE UNIT TO EXCESSIVE TEMPERATURES.

4.19 OUTPUT OFFSET

If the quiet day field strength is not midway between the maximum and minimum peak stormy values, then an output offset is required to fully utilize the recording range of the MPE.

Depending on whether positive, zero or negative offset is required, link R82 to the +, OFF, - point shown on the schematic, and adjust R84 for the desired offset.

4.20 SCALE-VALUE TESTS

With the loop switch OPEN, check the deflection for a positive current by moving the mode switch on the MCC-1 to MANUAL S.V. and the switch marked '+','OFF','-' to '+' and note the deflection of the spot on each MPE. Change the connections to the scale value coil (at the Helmholtz coil) if the deflection observed is reversed:

1. X unit, D Easterly. If the deflection is to the

   LEFT, the field is NORTHERLY and is CORRECT
   RIGHT, the field is SOUTHERLY and is REVERSED.

2. X unit, D Westerly. If the deflection is to the

   RIGHT, the field is NORTHERLY and is CORRECT
   LEFT, the field is SOUTHERLY and is REVERSED.

3. Y unit. If the deflection is to the

   RIGHT, the field is EASTERLY and is CORRECT
   LEFT, the field is WESTERLY and is REVERSED.

4. Z unit. If the deflection is to the

RIGHT, the field is DOWNWARDS and is CORRECT
LEFT, the field is UPWARDS and is REVERSED.

When the loop is closed and an automatic scale-value test is initiated via the MCC-1 Controller, the initial recorder deflection should be positive.

The scale-value coil is a single turn, wound under the feedback coil. The theoretical coil constant is 8.03 nT/mA. If scale-value determinations indicate that scale-value adjustment is necessary, readjust R47, keeping the loop closed.

4.21 ORIENTATION CHECK

With all units operating, observe each MPE output with a voltmeter or a chart recorder.

Apply the maximum ORIENT field to each component. If an output changes, the magnet concerned is no longer correctly oriented (owing to field changes since the orientation was adjusted).

NOTE.
A small change in output from the LA COUR Z-BALANCE may be disregarded, since the magnet may not be perfectly oriented (refer section 4.5).

If necessary, repeat the final orientation procedure as described in 4.7.

4.22 INSULATING COVER

If a thermally insulating cover or light shield is to be used (see Section 3), place it over the MPE, taking care not to disturb the orientation.

This concludes the setting-up procedure.

5. SUMMARY SETTING-UP PROCEDURE

This description is a summary of steps detailed in Chapter 4. For extra details refer to that chapter under the corresponding section number (e.g. full details for procedures described in Section 5.3 can be found in Section 4.3).

5.1 EQUIPMENT REQUIRED

Controller, B.M.R. Type MCC-1
CRO with two-channel summing capability
Digital multimeter
Bubble level
Tommy-bar, non-magnetic
Measuring scale, non-magnetic
Screwdrivers
Stopwatch
Compass
Try-square
White card
Heater and portable variometer for temp compensation

5.2 MECHANICAL ALIGNMENT

Orient the MPEs on their respective piers, as follows:

X UNIT (Refer to Fig 4.1)
Helmholtz coil at the eastern end if D is easterly
or
Helmholtz coil at the western end if D is westerly.

Align orient coils north-south (axis east-west).

Y UNIT (Refer to Fig 4.2)
Helmholtz coil at the northern end.

Align orient coils east-west (axis north-south).

Z UNIT
Helmholtz coil at the eastern (western) end.

Magnet within +/- 10 degrees of magnetic north-south with north seeking end pointing north.

Align orient coils to vertical (axis horizontal).

5.3 SENSOR HEIGHT

Mount sensors on their respective pillars and adjust their vertical heights so that the magnet of each sensor is centred in its Helmholtz coil.

5.4 OPTICS --- INITIAL SETTING

1. QHM
   Adjust the front plate of the electonics so it is centered vertically about the mirror.

2. LA COUR Z-BALANCE
   Adjust the front plate of the electronics to about 5 mm below its highest position.

For both QHM and La Cour, adjust the lateral position of the LED and the photodiode for symmetry with respect to the sensor.

5.5 MAGNET ALIGNMENT

1. QHM

   X UNIT, D EASTERLY
   Unclamp the magnet and torsion the fibre clockwise until the mirror is transverse to the MPE base.

   X UNIT, D WESTERLY
   Unclamp the magnet and torsion the fibre anti-clockwise until the mirror is transverse to the MPE base.

   Y UNIT, D EASTERLY
   Unclamp the magnet and torsion the fibre anti-clockwise until the mirror is transverse to the MPE base.

   Y UNIT, D WESTERLY
   Unclamp the magnet and torsion the fibre clockwise until the mirror is transverse to the MPE base.

2. LA COUR Z-BALANCE

   Grind the magnet for horizontal balance.

5.6 OPTICS --- COARSE ADJUSTMENT

Connect power to the MPE via the MCC-1. Ensure the loop swith is in the OPEN position.

Remove the rear cover of the electronics and adjust R49 fully clockwise.

Adjust the position of the LED to centre the light beam on the lens of the sensor. If excessive lateral adjustment is necessary rotate the LED in its holder to confine the offset to the vertical plane.

5.7 FINAL ORIENTATION

1. X UNIT
Release the magnet and torsion the fibre until a reflected light spot appears on the photodiode.

For D easterly, use a +ve ORIENT current. For D westerly, use a -ve ORIENT current.

Apply the ORIENT current; note direction of spot movement; remove current and adjust torsion in the direction of the motion and repeat until no deflection is noticed with application of current.

2. Y UNIT
Release the magnet and torsion the fibre until a reflected light spot appears on the photodiode.

Apply a +ve ORIENT current. Note direction of spot movement; remove current and adjust torsion in the direction of the motion and repeat until no deflection is noticed with application of current.

3. Z UNIT
Orientation is satisfied when the magnet has been balanced for the ambient Z field.

Adjust the mirror to its highest position possible so that the reflected light spot is at the same level as the photodiode.

Rotate the mirror support bracket so that the reflected light spot is near the centre of the photodiode.

5.8 FOCUSING

Adjust the longitudinal position of the electronics assembly for the best focus of the reflected light spot on the photodiode. Recheck the angle of the LED and the vertical position of the front plate.

5.9 LOOP SWITCH FUNCTIONS

1. CLOSED Normal operating position, seldom used in setting up.

2. OPEN Most of the setting-up proceedure is done in this mode.

3. SET GAIN A current is applied to the Helmholtz coil for gain setting and calibration.

5.10 ELECTRONIC OFFSET ADJUSTMENT

Remove the link between A4 and A5 amplifier stages.

Adjust R22 for 0.000 volts between M3 and a ground close to A7 pin 3.

Adjust R27 to approx. the centre of its range.

Adjust R30 for 0.000 volts between M4 and a ground close to A8 pin 3.

Adjust R32 and R37 fully anticlockwise.

Adjust R36 for 0.000 volts between point F on the printed circuit board and ground with the loop switch in the OPEN position, readjust for zero drift when the loop switch is moved to the CLOSED position.

Refit the link.

5.11 INITIAL CALIBRATION

Measure the voltage, Vc, at M5 with the loop switch in the SET GAIN position.

Connect a meter to measure the current in the feedback coil and adjust R47 to give a current of:

1.038*Vc mA.

when the loop switch is in the SET GAIN position.

5.12 COMPENSATION NETWORKS

Measure the free period of the QHM/La Cour magnet, Tav.

Adjust the four resistance networks, R31 + R32, R33 + R37, R38 + R39, R40 + R41, to equal:

72.34*(Tav) kohms.

5.13 OPTICAL SENSITIVITY

Darken the room.

Connect a two channel CRO to M6 and M7.

Turn R49 fully clockwise (if not done in step 5.6).

Set the CRO to measure the sum of the two signals and adjust the vertical position of the front plate to give the maximum signal level.

Adjust R49 until to signal amplitude is 800 mV peak-to-peak.

5.14 A.C. GAIN

With loop OPEN and the light spot laterally centred on the photodiode (minimum signal at M2), move the loop switch to SET GAIN, if the peak signal at M13 reaches or exceeds 10 volts with the low-gain strap removed, install the strap. Restore the loop switch to OPEN.

5.15 FEEDBACK AND OUTPUT POLARITIES

Observe the direction of the motion of the light spot when the loop switch is moved from OPEN to SET GAIN, if the directions are not as follows, reverse the connections to the feedback coil.

X UNIT movement to the right, for D Easterly.

X UNIT movement to the left, for D Westerly.

Y UNIT movement to the left, For D Easterly.

Y UNIT movement to the right, for D Westerly.

Z UNIT movement to the left.

With the loop switch at OPEN measure the waveform at M4 with the CRO. The waveform will appear as a baseline with spikes at the chopper frequency. Adjust the horizontal position of the photodiode so that the base line is at zero volts. Move the loop switch to SET GAIN and note the level shift of the baseline; it should be in a positive direction, if not, reverse the connection to the photodiode.

5.16 LOOP GAIN

With the CRO connected as above, adjust R27 so that a change from OPEN to SET GAIN of the loop switch will produce a change of 5.0 volts at M4.

5.17 ESTABLISHING THE REFERENCE OUTPUT

Remove all magnetic material from the vicinity of the MPE, adjust the lateral position of the photodiode to give zero volts output at point F1 on the circuit board, or on the chart recorder, when the loop switch is CLOSED.

5.18 TEMPERATURE COMPENSATION

If compensation is not required, link R74 to ground. Otherwise, adjust R83 for 0.00 volts at J2/H at normal operating (reference) temperature. Heat the MPE by a few degrees and allow to reach thermal equilibrium. Note the change in output caused by the temperature increase and, with R74 linked to + polarity, back off this change with R75. If the polarity is reversed, change the link on R74 to - polarity. Repeat until there is no output change due to heating ONCE THE TEMPERATURE HAS STABILIZED. If possible, use a portable variometer to monitor actual field changes while the MPE is heating up and make the necessary corrections; otherwise select a magnetically quiet day and/or repeat the adjustment for satisfactory compensation.

5.19 OUTPUT OFFSET

Link R82 for the desired polarity and adjust for the desired offset. Leave the link open if offset is not required.

5.20 SCALE-VALUE TESTS

With the loop switch set to OPEN, note the direction of the spot motion when a +ve scale value field is applied to the MPE. If the direction is not as set out below, reverse the connections to the scale value coil at the Helmholtz coil.

X UNIT, D easterly, deflection to the left.

X UNIT, D westerly, deflection to the right.

Y UNIT, deflection to the right.

Z UNIT, deflection to the right.

5.21 ORIENTATION CHECK

Measure the output voltage at point F, or on the recorder, when the loop switch is CLOSED.

Apply a maximum ORIENT field, If the output changes, repeat 5.7.

A change in the output of the LA COUR Z-BALANCE is acceptable.

5.22 INSULATING COVER

If used, fit the insulating cover.

6. CIRCUIT DESCRIPTION

Refer to the schematic diagram, MPE-1 Sheets 1, 1a.

6.1 PHOTODIODE AND TRANSRESISTANCE AMPLIFIERS

The light detector, CR10, is a Schottky-barrier lateral-effect photodiode, "United Detector Technology" type PIN-LSC/4, with an active surface length of 10 cm or, in later units, PIN-LSC/30D, with an active surface length of 3 cm. It is operated in the photoconductive mode, i.e. into a low resistance which, in this circuit, is essentially zero, being the virtual earths of operational amplifiers A1 and A2.

Reverse bias, usually used to increase response speed, is, in this case, needed to swamp the effects of amplifier bias currents. Approximately -1.4 volts is applied between anode and cathode by the voltage divider R1 and R2, bypassed by C1.

The total current from the cathode of the photodiode is proportional to the intensity of the light incident on the active surface. This current divides between the contacts at each end of the cathode in a ratio dependent on the position of the light spot with respect to the centre of the photodiode; the two currents are equal when the spot is central.

The photodiode cathode-contacts connect directly to the virtual earths of A1 and A2. The 1 Megohm feedback resistors, R3 and R4, give a transresistance of -1 V/uA for each of these amplifiers, i.e. for every microamp of current into the virtual earth, the output voltage reduces by 1 volt. Capacitors C2 and C3 ensure stability of these amplifiers by compensating for the capacitance of the input leads.

The choice of operational amplifier type LF356N for A1 and A2 was governed by the need for low noise, high input resistance, low bias current and wide bandwidth.

The high brightness LED light source is chopped at about 220 Hz. Thus, the outputs of A1 and A2 are 220-Hz positive-going square-waves whose sum is proportional to the total light intensity and whose signed difference measures the deviation of the light spot from the centre of the photodiode.

6.2 OPTICAL CONTROL LOOP

The optical control loop maintains constant optical "gain", regardless of aging or replacement of the LED or photodiode, or losses in the optical path. The sum of the outputs of A1 and A2 is proportional to the intensity of the light spot from the LED, the responsivity of the photodiode and the gain of the transresistance amplifiers. The sum of the outputs of A1 and A2 is kept constant by feedback, and thus the optical "gain" remains constant.

The outputs of A1 and A2 produce 220-Hz currents, in R5 and R6, which are summed, via coupling capacitor C8 and half-wave demodulator A13, into the virtual earth of A12.

A12 is connected as a summing integrator: the demodulated currents from A1 and A2 are summed together with a reference current set by R50 and the voltage preset by R49, a potentiometer connected across the precision -6.9-volt reference, CR8. Feedback action around the control loop keeps the sum of the currents from A1 and A2 always equal and opposite to the reference current. The value of the integrator capacitor, C38, sets the optical control loop time constant to be several times longer than the QHM natural period, thus preventing the loop from trying to track short-term changes in apparent light intensity caused by movement of the QHM mirror.

Q1 and Q2 form a Darlington emitter-follower which drives the LED ("STANLEY" type ESBRH500-0 or, in later units, the brighter ESBRH1000-0). R51 limits the maximum LED current to about 40 mA peak. For normal operation, R49 is set so that the sum of the outputs from A1 and A2 is 800 mV peak-to-peak, which requires a LED current of less than 35 mA peak.

R58 provides an on-card ground reference for the emitter of Q1. CR7 prevents the output of A12 from going negative and so damaging the base-emitter junctions of Q1 and Q2.

The Q output of the chopper oscillator, A14, is a 220-Hz square-wave, swinging between +6.8 V and -6.8 V. While the chopper output is positive, CR6 is reverse-biased and the current drive to Q2, and thus to the LED, is unaffected. During the negative half-cycles of the chopper output, CR6 is forward-biased and the 6.8-volt zener-diode, CR5, conducts in its reverse direction, shunting the Q2 drive current and thereby chopping the LED output at 220 Hz.

The half-wave demodulator, A13, consists of two CMOS bilateral switches labelled "A" and "C" on the schematic. (Switches B and D are not used.) Switch C is driven by the Q output of A14, and Switch A is driven by the antiphase NOT-Q output. Each switch turns on when its drive is positive, and turns off when its drive is negative. Thus the summed currents from A1 and A2 are connected to the virtual earth of A12 while the LED is on. While the LED is off, Switch C is off and Switch A is on, thus shorting the summed currents to ground and disconnecting the integrator. A13 therefore acts as a synchronous detector of the 220-Hz signals from A1 and A2.

6.3 DIFFERENTIAL AND A.C. AMPLIFIERS

The outputs from A1 and A2 are subtracted by unity-gain differential amplifier A3 to give a 220-Hz signal with an amplitude proportional to the distance of the light spot from the centre of the photodiode. If most of the current from the light spot flows into the virtual earth of A1, the output of A3, at monitor point M2, will swing from around zero volts to a negative level; if most of the photodiode current flows to A2, the signal at M2 will swing from around zero volts to a positive level.

The output of A3 is a.c. coupled to A4 by C11 and R15, which is returned to ground. The signal at A4 pin 3 is therefore a square-wave swinging symmetrically about zero volts and is either in phase or in antiphase with the chopper reference, depending on which side of the photodiode the light spot falls. (Note that there is essentially no signal when the main feedback loop is closed because the light spot is kept at the central null position; with the loop switch at OPEN, however, the signal may be observed as described.)

The gain of a.c. amplifier, A4, is set at 101 by resistors R16 and R17. Because later units have a brighter light source, more sensitive photodiode, and may be used with Z-Balances which are more sensitive than the QHM for which the earlier units were designed, this gain may be too high and cause saturation. To avoid this, R81 may be shunted across R17 by a hard-wire strap, reducing the gain to 2. The output of A4 is a.c. coupled by C14 to a synchronous full-wave demodulator circuit via a link which is removable for offset adjustments.

6.4 SYNCHRONOUS FULL-WAVE DEMODULATOR

A5 is connected as a unity-gain inverter so that antiphase signals appear at R25 and R26. A6 is a quad bilateral switch. Switches A and C operate identically to those in A13 --- see Section 6.2. Switches B and D operate similarly, except that the phases of their drive signals are reversed, giving full-wave detection. If, for example, Switch C is turned on by one half-cycle of the chopper, allowing, say, a positive current to pass through R25 and R10 from the signal at the link, then, on the next chopper half-cycle, Switch D will be turned on; the signal at the link will now be negative, but the current passed by Switch D, through R26 and R10a, will again be positive because of the inversion by A5. Full-wave detection reduces the amount of 220-Hz ripple fed to subsequent stages. The switching spikes which remain are reduced by C32 and C33.

Currents passed by A6 on successive chopper half-cycles are summed into the virtual earth of A7.

6.5 VARIABLE-GAIN D.C. AMPLIFIER

Adjustable gain is needed to set the loop gain for the required theoretical response. Potentiometer R27 sets the gain around A7. The overall gain from the link to M4 is:

$$R27/(R25 + R10) \qquad V\text{-}dc/V\text{-}peak$$

In the setting-up procedure, R27 is adjusted so that a field change of one nanotesla results in a thirty-three millivolt change at M4 --- see Section 4.16.

C20 is included to ensure the stability of this amplifier.

6.6 INTEGRATOR AND FIRST COMPENSATION NETWORK

A8 is connected primarily as an integrator, with C24 as the integrator capacitor and R31 + R32 as the input resistance. However, addtional components are added to obtain a lead-lag network for loop compensation. The lead is obtained by R33 + R37 in conjunction with C24; the lag results from C21 in conjunction with R33 + R37. Adjustment details for these networks are given in Section 4.12.

The output of the integrator forms the output of the forward path of the feedback loop. Output for a chart recorder, or other form of data acquisition system, is buffered by two cascaded unity-gain amplifiers A11 and A17, type OP07CJ, chosen for low voltage offset and drift. R57, in series with the output of A17, isolates the capacitance of the recorder cables.

6.7 OUTPUT OFFSET ADJUSTMENT

Potentiometer R84 connects across the voltage reference CR8; the wiper voltage sets the current in R82. This current is summed into the virtual earth of A11 or A17, depending on whether positive or negative offset is required. This selection is made by a hard-wire link which is omitted for no offset. R82 sets the possiible offset range to be in excess of 8 volts.

6.8 SECOND COMPENSATION NETWORK

A9 is connected as a unity-gain inverter for d.c. The capacitors associated with this stage provide the second lead-lag compensation network. The lead results from C25 + C26 in conjunction with R38 + R39; the lag results from C29 in conjunction with R40 + R41. The two resistor networks must be equal for unity d.c. gain; full adjustment details are given in Section 4.12.

6.9 LOOP SWITCH

S2 is a three-position toggle switch having unusual features which require explanation. On the schematic, S2 is shown in the CLOSED position: there is a connection from the output of A9 to the following stage, and the integrator circuit (A8) is in its normal state.

When the actuator of S2 is moved to its central position, OPEN, only sections "a" and "c" of S2 change over; sections "b" and "d" remain as shown on the schematic. The control loop is thus opened because A9 is disconnected from the following stage; the integrator circuit is unaffected.

When the switch actuator is moved from OPEN to SET GAIN, sections "a" and "c" remain as in the OPEN position and sections "b" and "d" change over. A9 is still disconnected from the following stage and the integrator capacitor, C24, is discharged through R37; A8 becomes a low-gain lagged amplifier.

This configuration allows observation of the forward path response when the loop is open --- a possibility which would be precluded by integrator drift if a pure integrator remained. Furthermore, in the SET GAIN position, section "d" allows a known current to flow to the following stage for calibration and gain adjustments.

6.10 COIL DRIVER

A10 is connected to convert the output voltage from A9 to a corresponding current to drive the feedback Helmholtz coil.

Q3 and Q4 are complementary emitter-followers to boost the available current. Neither side of the feedback coil is grounded; the coil connects between the output of the booster transistors and the local feedback network which consists of a shunt resistance, R46 + R47, to ground, and the feedback resistor, R45. The transconductance of the coil driver is thus:

$$-(1/R44)(1 + R45/(R46 + R47)) \quad A/V$$

The nominal value is -1 mA/V, but R47 is adjustable in order to set the overall magnitude of the "gain" of the coil driver and the feedback Helmholtz coil at 100 nT/V. (The nominal coil constant is 96.4 nT/mA.)

The purpose of the back-to-back zener diodes, CR1 and CR2, is to eliminate any inductive voltage spikes which may be generated by sudden current changes in the coil. C30 is included for stability.

In the SET GAIN position of the loop switch, an equivalent input voltage to the coil driver of approximately -1.51 volts is derived from the -6.9 volt reference, CR8. This produces a field of about 151 nT when R47 is correctly set. Instructions for this initial calibration are given in Section 4.11. Furthermore, once the calibration is set, this test field may be used to set the loop gain --- see Section 4.16.

6.11 CHOPPER OSCILLATOR

A14 is a CMOS astable multivibrator operating at a nominal frequency of 227 Hz. This frequency was chosen to avoid beats with mains harmonics and to ensure that the a.c. signal in the input stages has a frequency high enough to avoid the 1/f and low-frequency burst noise sources associated with active devices; at the same time the frequency is low enough for square-waves to be passed with little waveform distortion. The frequency, set by R54 and C39, is not critical.

The outputs of the chopper swing symmetrically between plus and minus 6.8 V, enabling the switches in the demodulators, A6 and A13, to handle both positive and negative inputs.

6.12 TEMPERATURE COMPENSATION

CR11 is a precision integrated circuit temperature sensor mounted at each QHM and Z-Balance where it shares a similar thermal environment to the magnet. The output of CR11 is -10 mV per degree Kelvin, and it is biased at about 1.3 mA by R64 and R65, decoupled by C40. The wires connecting CR11 are twisted for minimum magnetic field.

One half of A15 forms a unity-gain differential amplifier; its output is the difference between the voltage across CR11 and the adjustable voltage set by network R68, R71 and R83. R83 is adjusted to give zero output at some reference temperature.

The second half of A15 inverts the output of the first half so that A16 may be connected via a hard-wire link for either a posiive or a negative temperature coefficient. The link connects to ground if compensation is not used.

A connection to J1/H provides an output proportional to temperature.

A16 is a d.c. amplifier with gain adjustable by R75 to give the required level of compensation. Its output voltage produces a current through R76 into the summing junction of coil driver amplifier A10. Thus a field is produced in the feedback Helmholtz coil which counters the effect of the magnet's temperature coefficient.

6.13 POWER SUPPLIES AND LAYOUT

The MPEs operate from plus and minus 15 V supplies located in the MCC-1 Controller. Worst-case current demands for one component are 200 mA from the positive supply and 150 mA from the negative supply.

Considerable attention was given to component layout, and to power supply and earth routing on the printed circuit board to avoid instability from spurious feedback to the high-gain input stages. Extensive power supply bypassing and decoupling was included for the same reason. In particular the LED current must not flow in the supply or earth leads serving other parts of the circuit.

All CMOS circuits, i.e. A6, A13, A14, are supplied from plus and minus 6.8 V derived from the 15 V rails by zener diodes CR3 and CR4.

6.14 CONNECTORS

J1 connects the MPE to the MCC-1 Controller; the connections to the Helmholtz coil system and temperture sensor are made through J2.

Fig. 2. SE QLD SEISMIC SURVEY 1984
Locality map

R8503904

Drawn	Date	Checked	Amendments	Issue
[illegible]	17/9/82			1
[illegible]	5/10/82		VARIOUS	2
[illegible]	27/1/83		—	3
[illegible]	26/3/84		[illegible] ADDED	4
F. CLEMENTS	14-1-85		J1/F TO J2/A LINK INSERTED. WIRE COLOURS MODIFIED J1/J2.	5
[illegible]	3.8.85		TEMPERATURE COMPENSATION CCT ADDED SH. 1a	6
[illegible]	10/10/85		M13, COLOUR CODE ADDED	7

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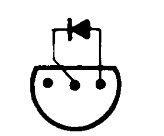

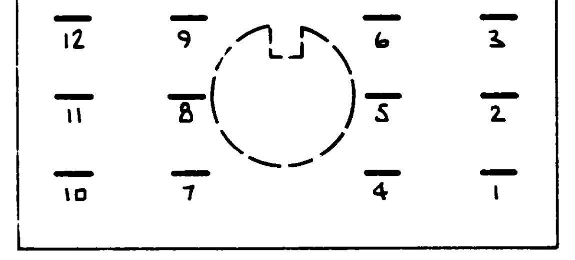

Drawing No.	Sheet No.	Title:
M8	1	MPE-1 Photo Electronic Magnetometer Schematic

Drawn	Date	Checked	Amendments	Issue
R. Carr	2/9/85		REDRAWN	1

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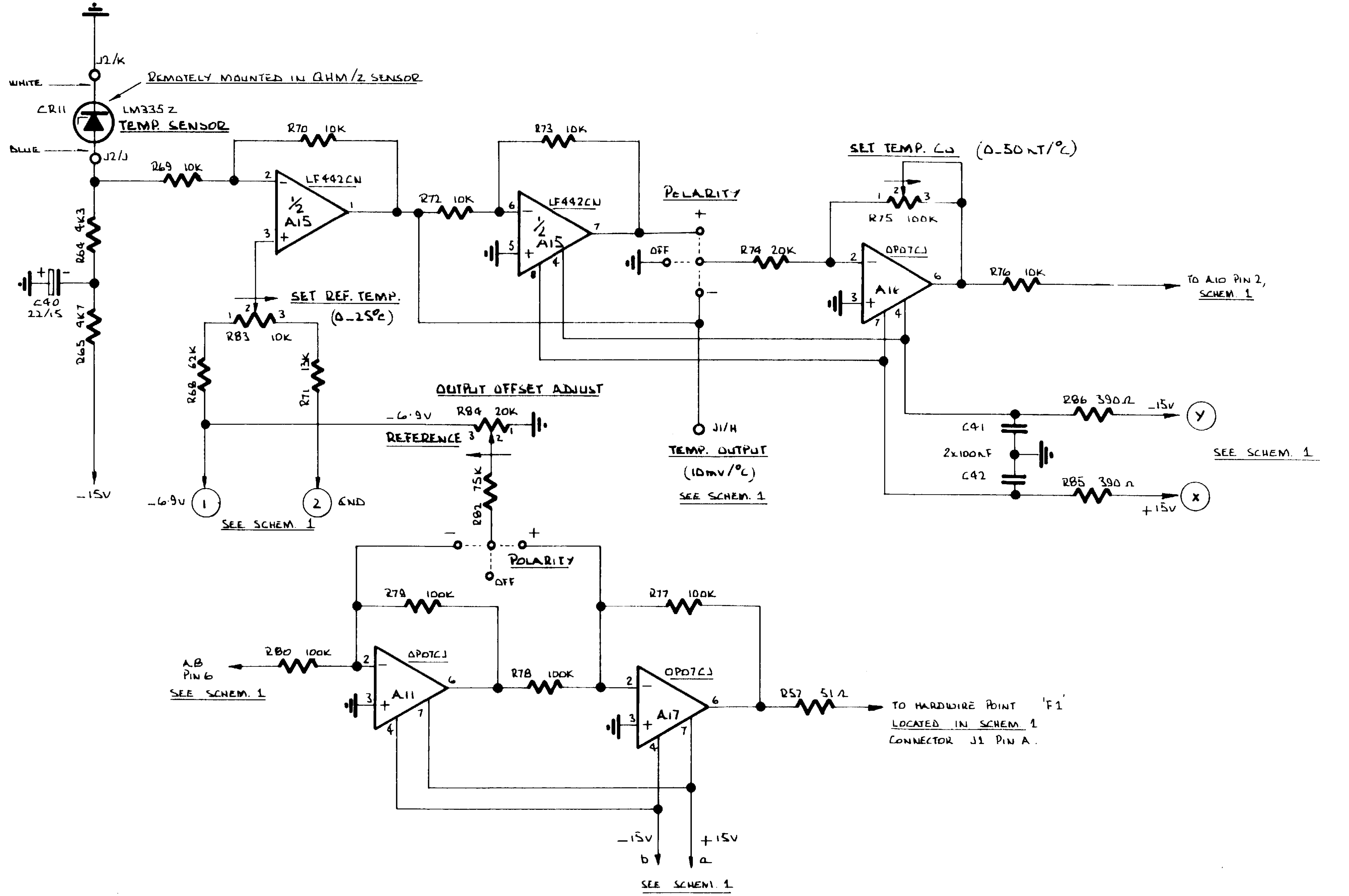
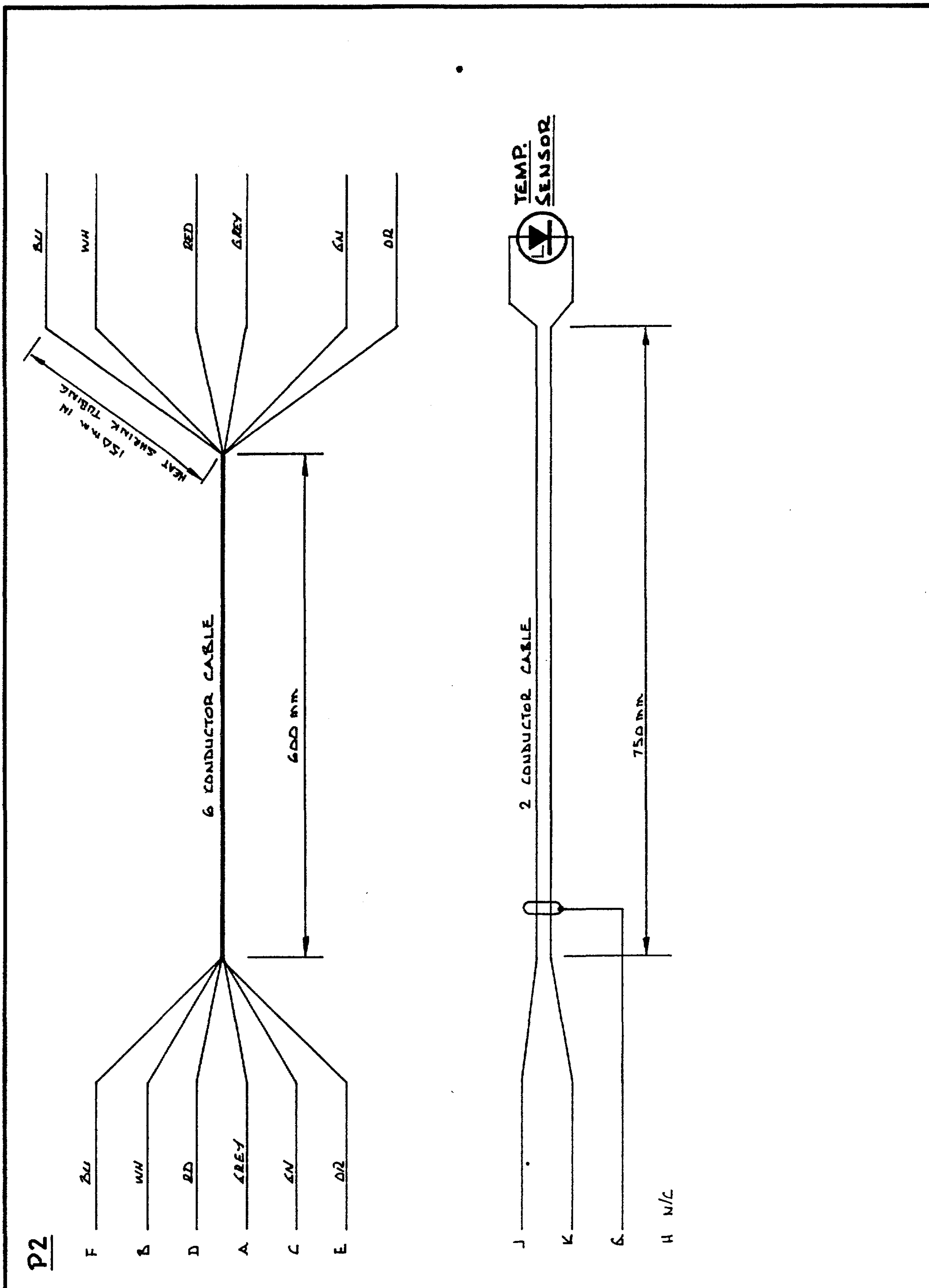
LM335Z



Drawing No.	Sheet No.	Title:
MB	1a	TEMPERATURE COMPENSATION CIRCUIT. ADDED ON TO PHOTO-ELECTRONIC MAG. MPE-1

R8503905



Bureau of Mineral Resources, Geology and Geophysics,	**Drawing No.** M8	**Issue**	**Title:** INTERCONNECT CABLE
	Sheet No. 1a(i)	1	
P.O. Box 378, Canberra City, A.C.T. 2601	**Drawn** [signature] **Date** 9/8/85		TO HELMHOLTZ COIL

1980 B

Item	Value	Vw	Tol %	Type	Make	Maker's Ref	BMR Vocab	Qty
A1-5, 7, A8, 12.	8-PIN	D.I.P		OPERATIONAL AMPLIFIER	NATIONAL	LF356N	N.I.V	8
A6, 13.	14-PIN	"		QUAD BILATERAL SWITCH	RCA	CD4066BE	BUC-4066	2
A9-11	8-PIN	"		OPERATIONAL AMPLIFIER	NATIONAL	OP07CJ	BUA-OP-07CJ	3
A14	14-PIN	"		CMOS I.C. MONOSTABLE/ASTABLE MULTIVIBRATOR	RCA	CD4047BE	BUC-4047	1
Q1, 2, 3.				TRANSISTOR, NPN		PN3643	BVT-PN3643	3
Q4				TRANSISTOR, PNP		PN3638A	BVT-PN3638A	1
CR1, 2.			5	ZENER DIODE, 3.3V @ 5mA.	PHILIPS	BZY 88-C3V3	BVD-3033	2
CR3, 4, 5.			5	ZENER DIODE, 6.8V @ 5mA	"	BZX79-C6V8	BVD-3068	3
CR6, 7.				SILICON DIODE	"	IN4148	BVD-IN4148	2
CR8			5	VOLTAGE REFERENCE DIODE, 6.9V.	NATIONAL	LM329BZ	N.I.V.	1
CR9				L.E.D., 660nm, ULTRA BRIGHT.	STANLEY	ESBRH-1000-D	N.I.V.	1
CR10				PHOTODIODE, LATERAL EFFECT, 10cm	UNITED DETECTOR TECHNOLOGY	PIN-LSC/30D	N.I.V.	1
C1	5.6nF	10	10	CAPACITOR, SOLID TANTALUM	SPRAGUE	TYPE 196D	BCJ-02565	1
C2, 3.	68pF	100	10	CAPACITOR, CERAMIC, VP	VITRAMON	VP22BY-680KB	BCA-1680	2
C4-7, C11-13.	100nF	100	10	CAPACITOR, CERAMIC, VP	"	VP22BY-104KB	BCA-1104	15
C18, 19, C21, 23, C29, 36, 37.	100nF	100	10	" " "				
C9, 10, 16, C17, 27, 28.	100µF	20	10	CAPACITOR, TANTALUM, CSR13	SPRAGUE	CSR13E 107KL	BCK-03107	6
CX1, 2.	100µF	20	10	EXTRA FILTERING IF REQUIRED CAPACITOR, TANTALUM, CSR13	"	"	"	2
C8, 14.	1µF	50	10	CAPACITOR, CERAMIC, CK	VITRAMON	CK06BX-105K	BCA-05105	2
C15	15pF	100	10	CAPACITOR, CERAMIC, VP	"	VP22BY-150KB	BCA-1150	1
C20	10pF	200		CAPACITOR, CERAMIC, CK	"	CK05BX-100K	BCA-2100	1
C25	330nF	63	0.5	CAPACITOR, PRECISION, POLYCARBONATE FILM	MFD	OPR330n D63	BCN-06334	1
C24, 26	2.2uF	63	0.5	CAPACITOR, PRECISION POLYCARBONATE FILM	"	OPR2u2 D63	BCN-06225	2.

Bureau of Mineral Resources, Geology and Geophysics, P.O. Box 378, Canberra City, ACT 2601	Instrument: MPE-1 PHOTO-ELECTRONIC MAGNETOMETER	COMPONENTS COMPOSITE
		SHEET No. M8/1(i) ISSUE 1
	Module: MPE1	DRAWN KAM DATE 26/1/83

1980 A

Item	Value	Vw	Tol %	Type	Make	Maker's Ref	BMR Vocab	Qty
C30	27nF	50	10	CAPACITOR, CERAMIC, CK.	VITRAMON	CK06BX-273K	BCA-05273	1
C32, 33	820pF	200	10	CAPACITOR, CERAMIC, CK.	"	CK05BX-821K	BCA-2821	2
C34, 35	1000μF	25		CAPACITOR, ELECTROLYTIC, ALUM.	PHILIPS	2222-017 16102	BCE-03108	2
C38	180nF	50	10	CAPACITOR, CERAMIC, CK	VITRAMON	CK06BX-184K	BCA-05184	1
C39	(SELECT) 10nF	100	10	CAPACITOR, CERAMIC, VP	"	VP22BY-103KB	BCA-1103	1
C31	–			CAPACITOR NOT IN CIRCUIT				
				*RESISTORS SELECTED WITHIN 0.5% FROM 2% STOCK				
R1	22k	0.4W	2	RESISTOR, METAL FILM, MR25	PHILIPS	2322-151-42203	BRA-55223	1
R2	2K2	0.4	2	RESISTOR, " " "	"	... 42202	BRA-55222	1
R3, 4.	1MΩ	0.5	2*	RESISTOR, TIN OXIDE, MRS	WELWYN	TYPE MRS	BRB-56105	2
R5, 6.	100k	0.4	2*	RESISTOR, METAL FILM, MR25	PHILIPS	2322-151-41004	BRA-55104	2
R7-9, 11, R10, 10a	10k	0.4	2*	RESISTOR, " " "	"	... 41003	BRA-55103	8
R18, 19.	10k	0.4	2*		"	"	"	
R13, 14.	160Ω	0.4	2	RESISTOR, " " "	"	... 41601	BRA-55161	2
R15, 50.	1MΩ	0.5	2	RESISTOR, TIN OXIDE, MRS.	WELWYN	MRS	BRB-56105	2
R16	5k1	0.4W	2	RESISTOR, METAL FILM, MR25.	PHILIPS	2322-151-45102	BRA-55512	1
R17	510k	0.4	2	RESISTOR, " " "	"	... 45104	BRA-55514	1
R20, 21, 28, R29, 34, R35.	2k4	0.4	2	RESISTOR, " " "	"	... 42402	BRA-55242	6
R22, 30, R36.	20k			POT. P.C.B. MOUNTING 25 TURNS	ALLEN BRADLEY	85W	N.I.V.	3
R23, 24	130Ω	0.4	2	RESISTOR, METAL FILM, MR25.	PHILIPS	2322-151-41301	BRA-55131	2
R25, 26.	91k	0.4	2*	RESISTOR, " " "	"	... 49103	BRA-55913	2
R27	1MΩ			POT P.C.B. MOUNTING. 25 TURNS	ALLEN BRADLEY	85W	N.I.V.	1
R31, 33, R38, 40.	51k	0.4	2	RESISTOR, METAL FILM, MR25.	PHILIPS	2322-151-45103	BRA-55513	4
R32, 37, R39, 41.	500k			POT. P.C.B. MOUNTING. 25 TURNS	ALLEN BRADLEY	85W	N.I.V.	4
R48	1k8	0.4	2	RESISTOR, METAL FILM, MR25.	PHILIPS	2322-151-41802	BRA-55182	1

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		SHEET No. M8/1(ii) ISSUE 1
	Module: MPE1	DRAWN KAM DATE 27/1/83

1980 A

Item	Value	Vw	Tol %	Type	Make	Maker's Ref	BMR Vocab	Qty
R42, 43.	82Ω	0.4	2	RESISTOR, METAL FILM, MR25.	PHILIPS	2322-151-48209	BRA-55820	2
R44, 45, R54.	100k	0.4	2	RESISTOR, " " "	"	... 41004	BRA-55104	3
R49	10k			POT. P.C.B. MOUNTING. 15 TURNS	ALLEN BRADLEY	85W	N.I.V.	1
R51	270Ω	1W	2	RESISTOR, TIN OXIDE, TR6.	ELECTRONIC	TYPE TR6	BRC-52271	1
R52	30k	0.4	2	RESISTOR, METAL FILM, MR25.	PHILIPS	2322-151-43003	BRA-55303	1
R55, 56.	1k3	0.4	2	RESISTOR, " " "	"	... 41302	BRA-55132	2
R57	51Ω	0.4	2	RESISTOR, " " "	"	... 45109	BRA-55510	1
R58	1k	0.4	2	RESISTOR, " " "	"	... 41002	BRA-55102	1
R59	300k	0.4	2	RESISTOR, " " "	"	... 43004	BRA-55304	1
R60	56k	0.4	2	RESISTOR, " " "	"	... 45603	BRA-55563	1
R63	10k	0.4	2	RESISTOR, " " "	"	... 41003	BRA-55103	1
R46	750Ω	0.4	2	RESISTOR, " " "	"	... 47501	BRA-55751	1
R47	500Ω			POT. P.C.B. MOUNTING. 15 TURNS	ALLEN BRADLEY	85W	N.I.V.	1
R12, 53, R61, 62.	-			RESISTORS NOT IN CIRCUIT				
M1-5 AND FLYING	LEAD CONNECTIONS			PINS, PCB MTG. PLUG (1mmØ)	CAMBION	460-2970-02-03-00	BHM-70	26
				SHORTING JACK, 1mmØ, SPACED 5mm.	"	450-3775-01-03-10	BHM-75	1
CONNECTORS FOR FLYING LEADS				LEAD MOUNTING JACK (1mmØ)	"	450-3367 01-03-00	BHM-71	18
J1	12-PIN			CONNECTOR, BOX MTG, RECEPTACLE.	CANNON	KPT 02E-14-12P	BKF-020	1
J2	10 PIN			CONNECTOR, BOX MTG, RECEPTACLE.	"	KPT-02E-12-10S	BKF-015	1
S2				SWITCH, TOGGLE, 4-PDT.	C&K	7411	N.I.V.	1
(S1)				NOT USED IN CIRCUIT				
SOCKETS	8-PIN	D/L		FOR A1-A5, A7-A12.	UTILUX	SERIES SO	BHS-39	11
SOCKETS	14-PIN	"		FOR A6, A13, A14.	"	"	BHS-40	3
BOX	DIECAST				EDDYSTONE	7970P	N.I.V	1

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Instrument: MPE-1 PHOTO-ELECTRONIC MAGNETOMETER

Module: MPE1

COMPONENTS COMPOSITE | SHEET No. M8/1(iii) | ISSUE 1 | DRAWN K.A.M | DATE 27/1/83

1980 A

Item	Value	Vw	Tol %	Type	Make	Maker's Ref	BMR Vocab	Qty
A15	8 PIN	D.I.P.		OPERATIONAL AMP.		LF 442 CN	N.I.V	1
A16, A17	"	"		" "		OP07CJ	BUA_OP_07CJ	2
CR11				TEMPERATURE SENSOR	NAT.	LM 335 Z	N.I.V.	1
C39, C40	22μF	15	10	SOLID TANT	SPRAGUE	CCR13D226K	BCK 03226	2
C41, C42	100nF	50	10	CERAMIC	VIT	CK06BX104K	BCA05104	2
R64	4K3		2	METAL FILM MR25	PHILIPS	2322-151 44302	BRA 55432	1
R65	4K7		"	" " "	"	44702	BRA 55472	1
R66, R67	———							
R68	62K		"	" " "	"	46203	BRA 55623	1
R69, 70, 72, 73, 76	10K		"	" " "	"	41003	BRA 55103	5
R71	13K		"	" " "	"	41303	BRA 55133	1
R74	20K		"	" " "	"	42003	BRA 55203	1
R77, 78, 79, 80	100K		"	" " "	"	41004	BRA 55104	4
R81	———							
R82	75K		"	" " "	"	47503	BRA 55753	1
R85, 86	390Ω		"	" " "	"	43901	BRA 55391	2
R75	100K			POT. P.C.B. MOUNTING. 25 TURNS.	ALLEN BRADLEY	85W	N.I.V.	1
R83	10K			" " " "	"	"	"	1
R84	20K			" " " "	"	"	"	1
				SHORTING JACK	CAMBION	REFER SH Viii)	BHM 75	2
				PINS P.C.B. MTG. PLUG	"	"	BHM 70	10

Bureau of Mineral Resources, Geology and Geophysics,
P.O. Box 378, Canberra City, ACT 2601

Instrument: MPE_1 PHOTO ELECTRONIC MAGNETOMETER
Module: TEMPERATURE COMPENSATION

COMPONENTS COMPOSITE
SHEET No. 1 (IV) | ISSUE 1
DRAWN [signature] | DATE 3/9/85

1980 A

MCC-1

MAGNETOMETER

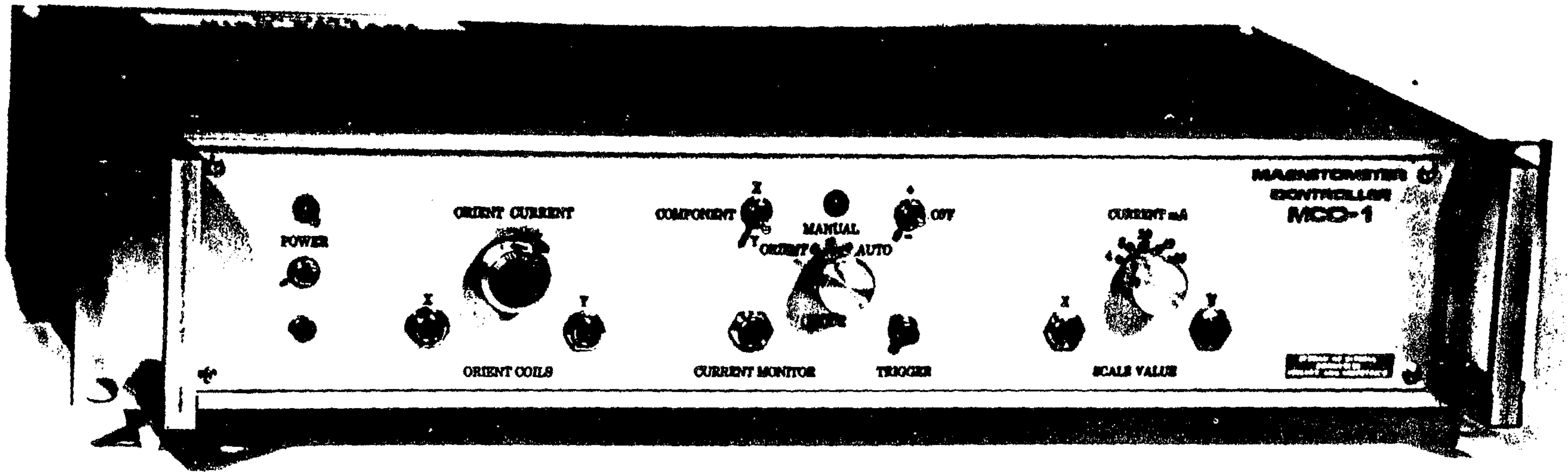
CONTROLLER

(2nd edition)

K.J. SEERS

and

G.W. BLACK


MAGNETOMETER
CONTROLLER
MCC-1
POWER
ORIENT CURRENT
COMPONENT
X
Y
MANUAL
AUTO
OFF
CURRENT mA
ORIENT COILS
CURRENT MONITOR
TRIGGER
SCALE VALUE

CONTENTS

FIGURES

GENERAL DESCRIPTION AND PERFORMANCE SPECIFICATIONS

1.1 GENERAL DESCRIPTION

The MCC-1 is an auxiliary instrument in the magnetic observatory installation of the BMR-designed MPE Photo-electronic Magnetometer. A typical installation comprises two MPE-1 and one MPE-2 units measuring orthogonal components of the earth's magnetic field (usually X,Y and Z), and one MCC-1 unit which provides the following facilities and functions:

* Plus and minus 15-volt power supplies for the MPE-1 units.
* A current source which may be used either to generate scale-value pulses or for sensor orientation (see MPE handbook).
* An automatic sequence of scale-value pulses which may be initiated locally or remotely.
* Connections for remote and/or local chart recorders to display the MPE outputs.
* Independent access to scale-value and orienting coils via front-panel jacks.
* Emergency power supply derived from external 24 volt DC supply.

The facing page shows a photograph of the MCC-1. The unit is housed in an instrument case measuring 88.9 mm high by 417 mm deep, and is suitable for either 19-inch rack mounting or bench mounting.

The various front and rear panel components and the internal power transformer connect, via hard wiring, to a single printed circuit board which contains the regulated power supplies, the current source and the control logic.

The unit operates from 240-volt 50-Hz mains power.

The MCC-1 was entirely designed and constructed in the Engineering Services Branch of BMR.

1.2 PERFORMANCE SPECIFICATIONS

POWER SUPPLIES FOR MPE

Plus and minus 15 V (within 5%) at 600 mA with current limiting and overload protection.

CURRENT SOURCE

ACCURACY: Within 2% of nominal scale-value current.

SWITCHABLE to any one of: X orient coil
Y " "
Z " "
X,Y and Z scale-value coil

POLARITY: Reversible.

ORIENT MODE: 0 to 30 mA by ten-turn potentiometer. Manual switching.

SCALE-VALUE MODE: 4, 8, 20, 40 or 80 mA, switch selectable. Single current step applied manually. Automatic sequence initiated by press-button, remote earthing contact or TTL logic LOW.

NOTE: The scale value coils for each component are connected is series. If one or more sensors are disconnected, it is necessary to use a dummy plug to maintain the scale value circuit.

AUTO SCALE-VALUE SEQUENCE: See Figure 1.1

POWER

240 V, 50 Hz at 65 mA typical.
Fuse 250 mA delayed action (Slo-blo)

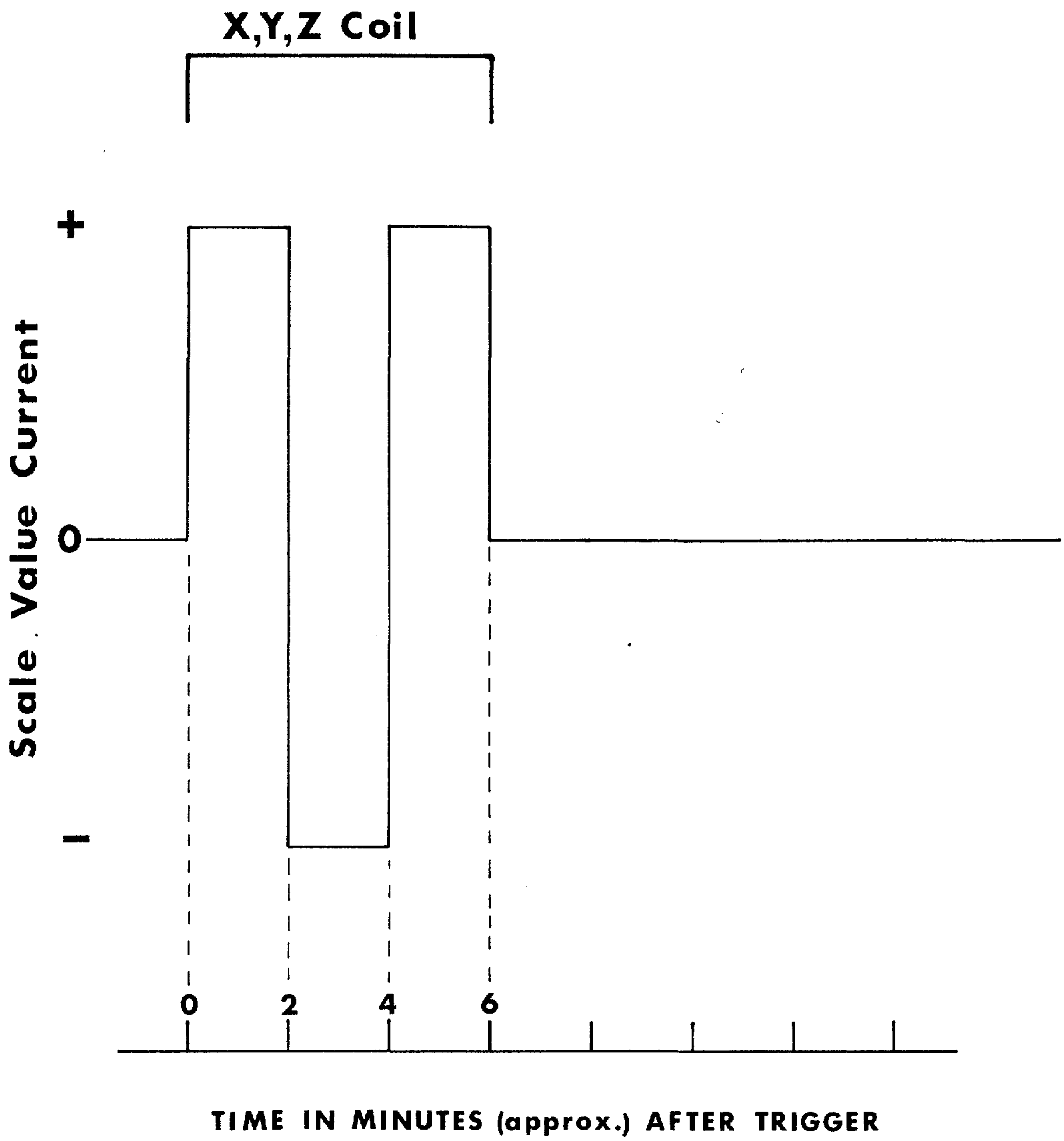


Fig. 1·1

AUTO SCALE-VALUE CURRENT SEQUENCE

2. BLOCK DIAGRAM DESCRIPTION

2.1 CURRENT SOURCE

Figure 2.1 is a block schematic of the current source circuit.

A six-volt reference is buffered by two unity-gain amplifiers, one inverting, the other non-inverting. The resulting positive or negative six-volt level is selected by signals from the control logic, which operate Switches A and B to give the desired output current polarity.

In the ORIENT position of S1, the positive or negative six volts is attenuated by the ORIENT CURRENT potentiometer to give continuous control over the output current. In the SCALE-VALUE position of S1, there is no attenuation; the six-volt level becomes the input to the following voltage-to-current converter.

The voltage-to-current converter is a Type 1 control loop consisting of a summing integrator, a current booster, a current sampling resistor and a differential amplifier. The integrator comprises an operational amplifier with input resistor R, and feedback capacitor C. The current drive capability of the integrator is boosted by a simple transistor amplifier, and the output current passes through the switched resistor Ro. The voltage across Ro is applied to the unity-gain differential amplifier and fed back to the second input of the integrator. When there is a load on the output, i.e. a connection (through the coil) to ground, the feedback action of the control loop keeps the voltage across Ro equal to the voltage at the input to the voltage-to-current converter, i.e. minus or plus six volts. Thus the output current, Io, is 6/Ro amps for the scale-value settings (MANUAL or AUTO) of S1, and continuously variable up to this value for the ORIENT setting.

Ro can take any of five values for scale-value currents of 4, 8, 20, 40 and 80 mA, and is fixed for the orienting current of up to 30 mA.

The output passes through K2, the current on/off relay operated by the control logic, and is routed via S1 to the scale-value coils or the orient coils via S2 to the X,Y or Z component.

To help increase the life of the relay contacts, the control logic operates Switches C and D immediately prior to the contacts opening. Before the contacts open, Switch C turns off and Switch D turns on; the integrator is disconnected from the source voltage and the capacitor, C, is rapidly discharged through Rd, thus reducing the current almost to zero. Similarly, the turn-on of the full current is delayed until after the contacts close.

2.2 CONTROL LOGIC

The block diagram of the control logic, Figure 2.2, should be considered in conjunction with Figure 1.1, the diagram of the auto scale-value current sequence.

On receipt of a trigger, which may be from the front panel press-button, from a remote contact closure, or from a logic level change in a data acquisition system (DAS), the reset is removed from the timing and counting logic.

The timing logic produces a pulse train with a period of approximately two minutes. These pulses are counted and decoded as shown, to select the current polarity, to activate the CURRENT-ON relay, K2, and to disable the integrator, all at the times required by the sequence of Figure 1.1. The decoded outputs are effective when the MODE switch, S1, (see Figure 2.1 and schematics) is in the AUTO position.

In the MANUAL SCALE-VALUE and ORIENT positions of S1, the manual override logic inhibits and resets the auto sequence; the CURRENT-ON relay, K2, is activated continuously, and the integrator is always enabled. In these modes, the current polarity is selected by a front panel toggle switch which controls Switches A and B of Figure 2.1. In the centre, or OFF, position of the toggle switch, the current is turned off by opening both Switch A and Switch B. A very small current may still flow to the MPE because of offset voltages in the voltage-to-current converter; at worst the zero error would amount to no more than 0.03% of the selected current range. No "off" current can flow in the AUTO mode because the circuit is broken by relay K2.

Also, in the ORIENT modes a second toggle switch selects the X,Y or Z MPE. Both toggle switches are disabled in the AUTO mode. A bright red light-emitting diode (LED) alerts the operator that the mode switch is in the MANUAL SCALE-VALUE or ORIENT position.

Recorder interconnections, power supplies, etc., are dealt with in following Sections.

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Drawing No. M8
Sheet No. 4
Issue 1
Drawn
Date 4/2/83
Title: MCC-1 BLOCK SCHEMATIC OF CURRENT SOURCE

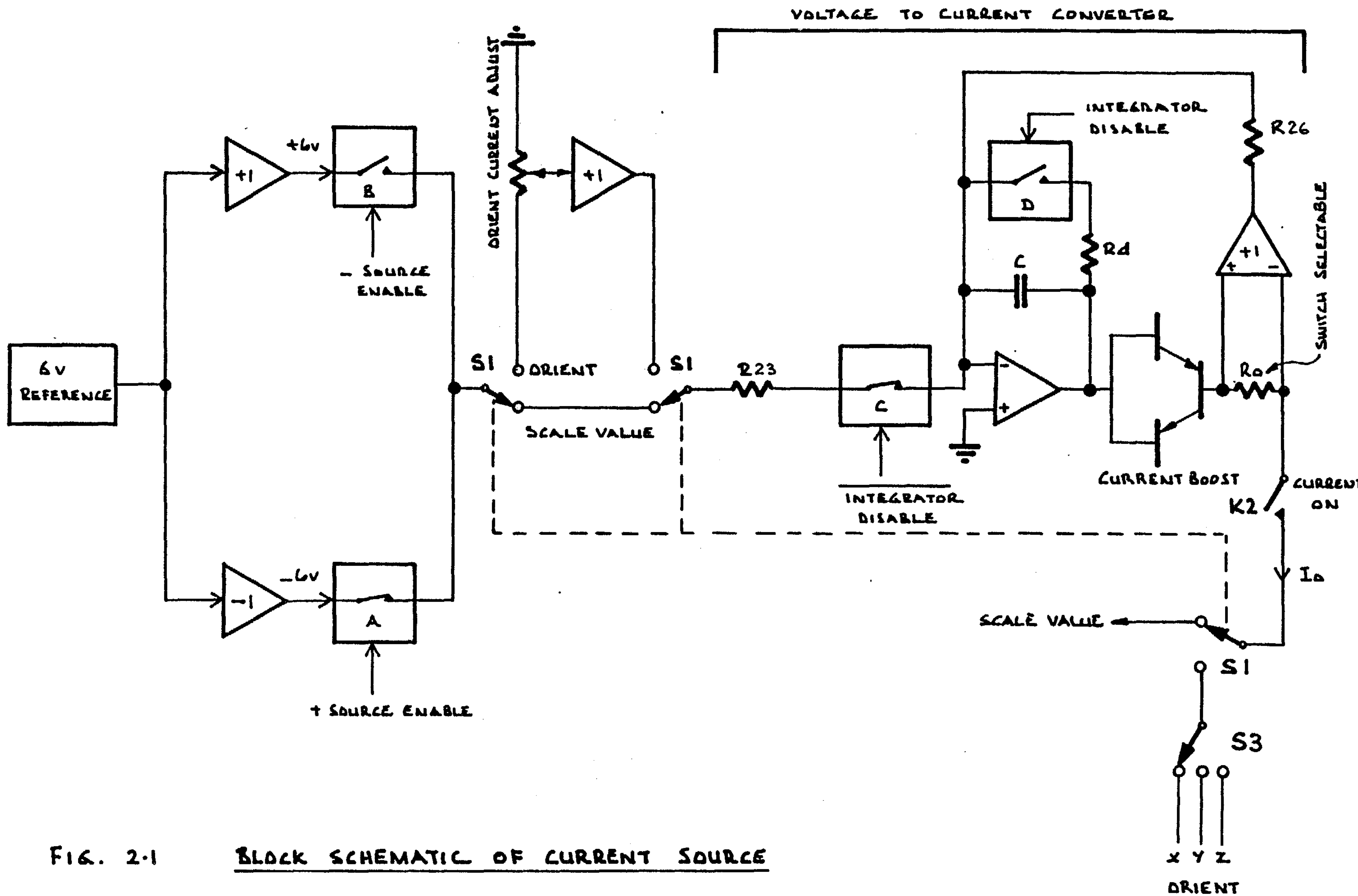


FIG. 2·1 BLOCK SCHEMATIC OF CURRENT SOURCE

1980 R

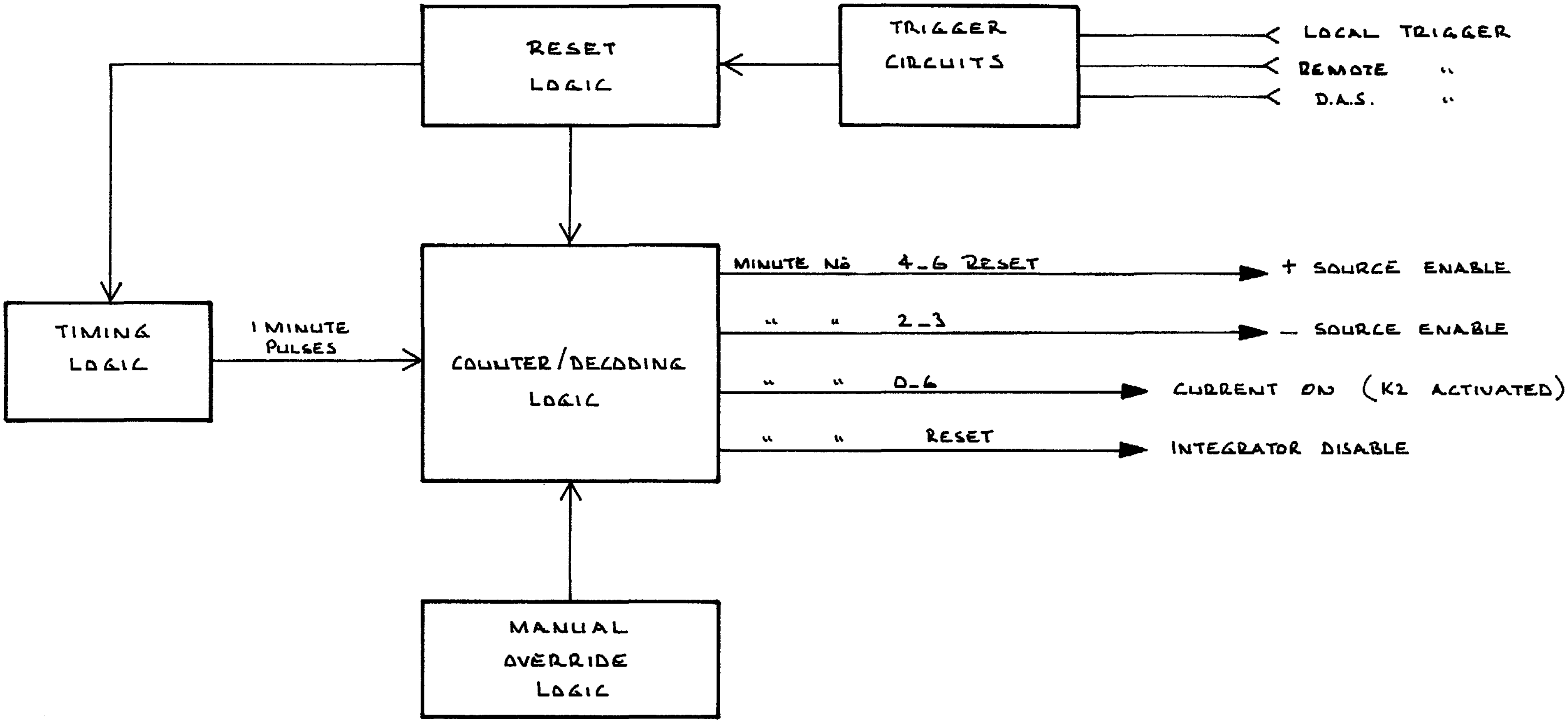


FIG. 2·2 BLOCK DIAGRAM OF CONTROL LOGIC

3. INSTALLATION AND OPERATION

3.1 INITIAL ADJUSTMENT

Connect the MCC-1 to 240-volt mains using the power cord supplied. (This cord has a moulded 3-pin female connector which mates with the receptacle on the rear panel of the MCC-1. Equivalent connectors are common on power cords for a variety of appliances and instruments, e.g. the Hewlett-Packard 7100B recorders which form part of the initial MPE-1 installation at Mawson.)

Remove the top cover of the MCC-1 and turn the power on at the front panel.

CAUTION

Although all live 240-volt connections are insulated, every precaution must be taken to avoid electric shock when working with the cover removed.

Refer to Schematic Sheet No. 2a, and connect a digital multimeter (DMM) between monitor point M1 and a ground point at or near A11 pin 3. Adjust R38, the only adjustment potentiometer on the printed circuit board, for 6.000 volts at M1. Disconnect the DMM and replace the cover. The MCC-1 may now be mounted in a 19-inch rack or may be left free-standing on a bench.

3.2 MPE-1 CABLING

Cables for connecting the MPEs units are supplied. Refer to J8, J9 and J12 on Schematic Sheet No. 3 for connector pin numbers. All connectors are labelled on the rear panel.

NOTE. If less than three MPEs are installed a dummy plug must be used in the vacant connectors positions to maintain the scale value circuit.

When connecting over long distances, or in areas prone to electromagnetic interference, e.g. near transmitters or generators, it is advisable to use twisted pair for recorder (O/P) cables. Preferably, use shielded twisted pair; provision is made for this on the MCC-1 connector. Shields should be terminated at the MCC-1 only; leave the MPE-1 ends floating to avoid earth loops.

Note that one side of each recorder output and the common line for the orient and scale-value coils in each MPE-1 are all at ground potential. Nevertheless, these all should be kept separate in the cabling to avoid interaction.

3.3 RECORDER CABLING

J6 (remote recorder) and J7 (local recorder), on Schematic Sheet No. 3, show the pin numbers for the recorder cables and for the remote auto scale-value trigger switch (pins E and F). Again, the use of twisted shielded pair is recommended for recorders and for the remote trigger circuit.

3.4 TRIGGER SOURCES

As well as from the press-button on the MCC-1 front panel, the auto scale-value current sequence may be triggered from a remote contact closure (between pins E and F on J6), or from a HIGH to LOW 5-volt logic level change connected through J11, an insulated BNC connector. Note that in the latter case, the grounds of the MCC-1 and the logic source are connected.

3.5 ACCESS TO MPE-1 COILS

Inserting a phone plug (tip and sleeve) into any of the front panel jacks, J2 or J5 (see Schematic Sheet No. 2a), disconnects the selected scale-value or orient coil from the MCC-1, allowing a current from an independent source to be connected via the phone plug. The common connections to the coils remain grounded in the MCC-1 however.

3.6 CURRENT MONITORING

The MCC-1 output current, whether to X, Y or Z, to scale-value or orient coils, may be monitored on a milliammeter plugged into phone jack J1 on the front panel (the central jack --- see also Schematic Sheet No. 2a). The meter is actually inserted into the common line for all coils.

3.7 FRONT PANEL CONTROLS

When the POWER switch is turned on, the green LED immediately above it indicates that the negative 15-volt regulator is working from the mains supply. While the yellow LED indicates that the negative 14-volt supply is working from the external 24-volt D.C. supply.

In the centre of the panel, the MODE switch has three positions:

In the ORIENT position, orienting current is fed to either the X, Y or Z orient coil, selected by the toggle switch at the top left of the MODE switch. The value of the orienting current is adjustable by the ten-turn ORIENT CURRENT potentiometer, which gives a linear increase from zero to approximately 30 mA. The polarity of the orienting current is selected by the toggle switch at the top right of the MODE switch. The current is off when the actuator of this toggle switch is in its central position.

In the MANUAL SCALE-VALUE position of the MODE switch, a scale-value current, set at 4, 8, 20, 40 or 80 mA by the CURRENT switch at the right of the panel, is fed to all the X, Y and Z scale-value coils with the polarity determined by the toggle switches.

In both the ORIENT and MANUAL positions of the MODE switch, the red LED immediately above it is on.

Once the MPE-1 units have been set up (see MPE-1 handbook), the normal position for the MODE switch is AUTO. In this position, the red warning LED is off, the toggle switch settings have no effect, and current can flow in the scale-value coils only. Scale-value current, set by the CURRENT switch, will flow in the auto sequence shown in Figure 1.1 whenever a trigger is received (see Section 3.4).

An auto trigger sequence can be terminated by momentarily setting the MODE switch to MANUAL.

4. CIRCUIT DESCRIPTION

Refer to Schematic Sheets Nos 2, 2a, 3.

4.1 VOLTAGE REFERENCE AND POLARITY SWITCHING

CR9 is a 6.9-volt reference biased from the +15-volt rail by R37. R16, R17, and potentiometer R38, form an adjustable voltage divider to give +6.00 volts at monitor point M1. A10 is connected as a voltage follower and A11 as a unity-gain inverter. Plus and minus six volts thus appear at the outputs of A10 and A11 respectively.

A13 is a CMOS quad bilateral switch operating between positive and negative 6.8-volt supply rails, and so able to accept bipolar voltage levels within this range. Switches A and B are operated by the control logic; each is turned on by a HIGH logic level on its control line. For positive output current, Switch A is turned on; Switch B is turned on (and Switch A off) for negative output current. R20 and R21 prevent excessive current flow during the simultaneous switching of Switches A and B.

The outputs of Switches A and B connect together and to one section of the MODE switch, S1a. For the AUTO SCALE-VALUE setting of this switch, the selected positive or negative six-volt source connects directly through S1b to R23, the input resistor to the integrator in the voltage-to-current converter.

In the ORIENT position of S1, the ORIENT CURRENT potentiometer, R24, buffered by voltage follower A12, provides continuously variable control over the voltage fed to R23.

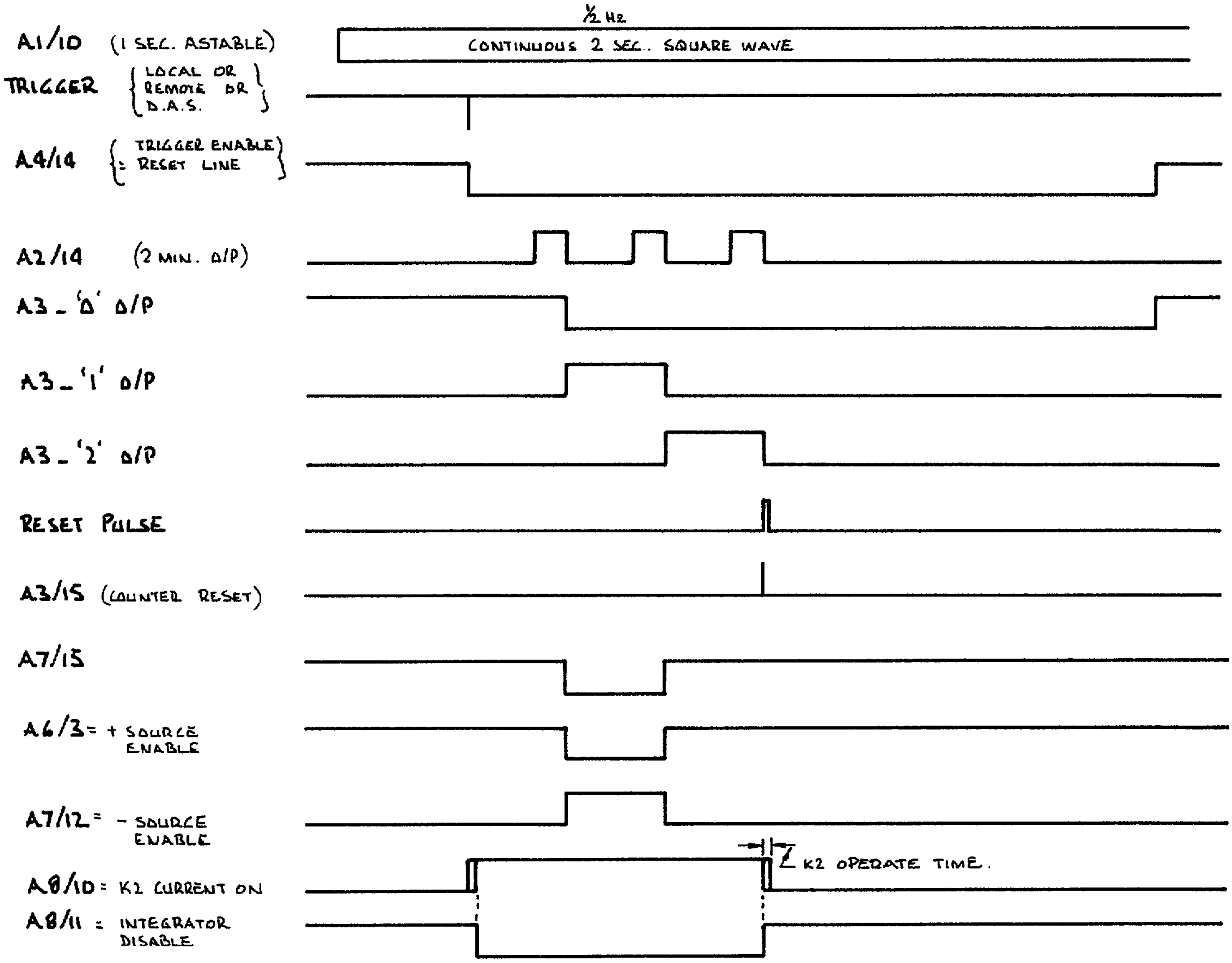
4.2 VOLTAGE-TO-CURRENT CONVERTER

This is described in principle in Section 2.1.

When Switch C is on, R23 is the input resistor to the integrator formed by A14 and C11. Complementary emitter followers, Q4 and Q5, boost the current drive capability of the integrator. When relay K2 is on, connecting a load coil, selected by S1e and K3, to ground, the output current flows through one of the resistors selected by the CURRENT switch, S5. The voltage across the selected resistor is measured by unity-gain differential amplifier A15, and fed to R26, a second input resistor to the integrator. Feedback action around this high gain loop causes the currents flowing into the two integrator inputs

S1: POS. 3 (SCALE VALUE AUTO.)

S2, S3 DON'T CARE



SEQUENCE

1 TRIGGER STARTS 6 MINUTE TIMING SEQUENCE. TRIGGER SOURCE DISABLED. K2 IS TURNED ON CONNECTING THE +VE CURRENT SOURCE TO THE CALIBRATE COILS TILL END OF MINUTE NO 2.

2 AT END OF MINUTE NO 2. CURRENT SOURCE CHANGES FROM +VE TO -VE

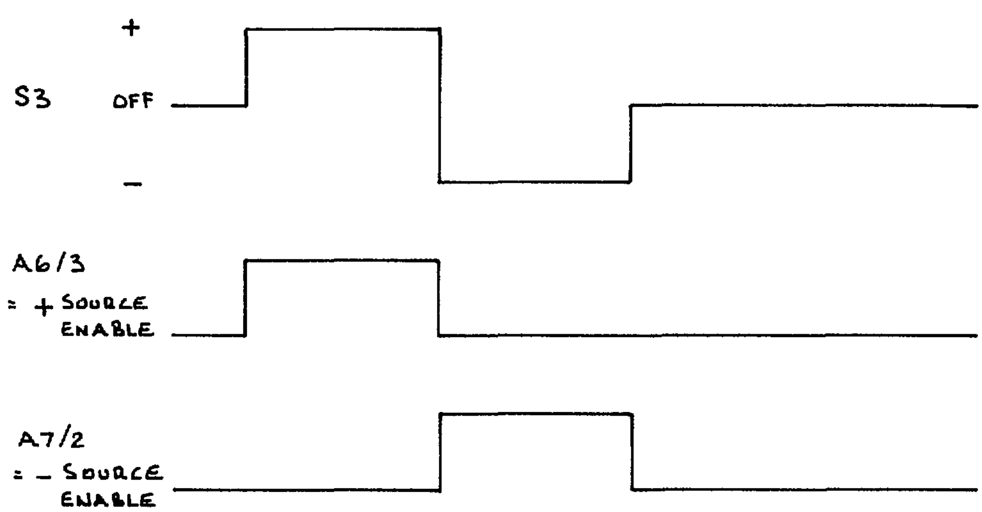
3 AT END OF MINUTE NO 4 " " " " -VE TO +VE

4 AT END OF MINUTE NO 6 INTEGRATOR IS DISABLED. (TURNING CURRENT OFF BEFORE K2 OPENS.) RESET PULSE INTEGRATOR DISABLED, K2 OFF, K3 OFF. (CHANGES LOAD BACK TO X COIL)

FIG. 4·1 LOGIC DIAGRAM — AUTO. OPERATION

S1: Pos. 2 (SCALE VALUE MANUAL) COUNTING LOGIC IS RESET BY S1G
(NOTE DIAGRAM IS IDENTICAL FOR S1 POS. 1 (ORIENT) — OUTPUT CURRENT GOES TO ORIENT INSTEAD OF SCALE VALUE COILS VIA S1e)

S4: DON'T CARE (i.e. TRIGGER SIGNALS MAY BE APPLIED IN MANUAL MODE, BUT WILL HAVE NO EFFECT.) IF SWITCHED FROM MANUAL BACK TO AUTO MODE (S1 POS. 3) AFTER RECEIVING A TRIGGER, THE AUTO CYCLE WILL OCCUR.



A8/10 ———————— HIGH
= K2 (CURRENT ON)

A8/10 ———————— LOW
= INTEGRATOR ENABLE

i.e. INTEGRATOR ON AND CURRENT ON FOR S1 IN POS. 1, 2

FIG. 4·2 MCC-1 LOGIC DIAGRAM — MANUAL OPERATION.

to be equal and opposite. For an input voltage, Vin, at R23, the voltage, Vo, across the selected resistor, Ro, is:

$$Vo = -Vin(R26/R23)$$

For positive scale-value current,

$$Vin = -6(R23/(R23 + R20))$$

Thus,

$$Vo = 6(R26/(R23 + R20))$$

$$= 6(110/(100 + 10))$$

$$= 6 \text{ volts}$$

Thus the magnitude of the output current, |Io|, is maintained at

$$|Io| = 6/Ro \text{ amps}$$

Ro corresponds to the resistor selected by S5, or S1d in the ORIENT mode.

Resistors R27 to R30 are matched to 0.5% for calibration accuracy.

In the AUTO mode, the integrator is disabled before relay K2 breaks the load circuit (and is enabled after K2 makes), to help extend the life of the relay contacts. Switches C and D receive control signals of opposite logic level. To disable the integrator, Switch C turns off, disconnecting the input voltage, and Switch D turns on, discharging C11 rapidly through R25. 6.8-volt zener diodes, CR10 and CR11, protect the CMOS switch from signal voltages exceeding its supplies.

4.3 COIL ACCESS AND MONITORING

J2 and J5 are phone jacks with normalling contacts. When a plug is inserted, the MCC-1 circuit is disconnected and the coil connects to the plug, allowing an independent current source to be used (but note that there must be a common ground with the MCC-1).

J1 is a similar phone jack in the common line for all coils. A meter connected to a phone plug inserted in J1 can thus monitor the MCC-1 output current.

4.4 LOGIC CIRCUITS --- GENERAL

Schematic Sheet No. 2 details the logic circuit connections. Figures 4.1 and 4.2 are logic diagrams showing the main relevant waveforms for the AUTO and MANUAL modes respectively, and should be considered with the schematic and with this description.

CMOS devices are used for all logic functions. They should be handled with care to avoid failures caused by electrostatic charge. They must be stored in conductive foam or foil; a person handling them should ensure he is earthed, and for working on the printed circuit board the tip of the soldering iron must be earthed.

4.5 TIMING LOGIC

A1 is connected as an astable multivibrator with a period of approximately two second set by R1 and C1,C1a,C1b,etc. The resulting 1/2-Hz square-wave is fed to A2, an industrial time-base generator which is triggered on the falling edges of the input pulses and divides the frequency by 60, giving a rectangular-wave with a period of about two minutes. This is fed to A3, a Johnson decade counter with decoded outputs, i.e. separate outputs which go HIGH for each of the zeroth (reset), first, second, third, etc., two minute pulses received.

In the AUTO mode, two inverters in A7 and A6 cause A3 to reset immediately after the sixth minute.

4.6 TRIGGER CIRCUIT

The AUTO sequence (see figure 1.1) may be initiated by a trigger from the MCC-1 front panel press-button, S4, by a remote contact closure to ground, or by a 5-volt logic LOW signal from a data acquisition system (DAS). For the remote or DAS operation, the LOW signal turns on Q1 via R11 or R12, thus activating relay K1. The single contact of K1 is in parallel with S4; operation of either will produce a LOW signal at A6 pin 12, which is the necessary condition to trigger the AUTO sequence.

The emitter supply for Q1 is from A9, a three-terminal 5-volt regulator, giving compatibility with TTL logic.

4.7 RESET CIRCUIT

A4 is a dual J-K flip flop with only one section used. In the RESET state the NOT-Q output, pin 14, is HIGH, so keeping A2 reset and inhibiting the output of one-minute pulses. A6 pin 13 is also kept HIGH, enabling the trigger signal to be received.

On receipt of a trigger signal, A6 pin 11 goes HIGH, clocking A4 so that its NOT-Q output goes LOW. This removes the reset on A2 and inhibits any further trigger inputs because of the LOW level at A6 pin 13.

The counting circuits then operate until the end of the sixth minute when the '3' output of A3 goes HIGH momentarily and resets A4 via A6 and A7. Two inverters in A6 and A7 insert a short time delay for resetting A3 , so giving a very short '3' output pulse.

4.8 COUNTING AND DECODING LOGIC

After the trigger has been accepted, A3 begins to count the two-minute pulses which are decoded and fed to NAND gates in A6. Here the time combinations necessary to perform the sequence of Figure 1.1 are decoded.

When the '1' output of A3 is HIGH, A7 pin 15 is LOW. This signal is inverted by each of two gates in A6 which are enabled by the manual override logic. A6 pin 3 provides the - SOURCE ENABLE signal which is HIGH during the third and fourth minutes. The + SOURCE ENABLE signal is derived from the same logic but is inverted by one section of A7, and so it is HIGH during the first and second also the fifth and sixth minutes.

The NOT-Q output of A4 is inverted at A8 pin 10, the gate in A8 being enabled by the manual override logic, and drives Q3 which activates the CURRENT ON relay, K2, at all times other than RESET.

The signal at A8 pin 10 is again inverted at A8 pin 11, but there is a short delay in enabling this gate because K2 must first operate to take A8 pin 13 HIGH. The signal at A8 pin 11 forms the INTEGRATOR DISABLE signal, and it is inverted by a section of A7 to give the NOT INTEGRATOR DISABLE signal. Thus the integrator is enabled (not disabled) only during minutes one to six, but the enabling is slightly delayed until K2 has operated, i.e. the relay contacts make before the load current builds up. Similarly, at the restoration of RESET, the INTEGRATOR DISABLE signal goes HIGH before the contacts of K2 have time to release, so the load current is reduced before it is broken by the relay contacts.

4.9 MANUAL OVERRIDE LOGIC

When S1 is in position 1 or 2 MANUAL SCALE-VALUE or ORIENT, S1g via A7 and A6 ensure that A2, the counting circuit, remains reset, and keeps A4 in the RESET state.

Further, S3, the '+','OFF','-' switch which in the AUTO mode is disabled by a low at A8 pins 2 and 5, is now enabled by a high at these pins.

Since A3 is held RESET when S1 is not in the AUTO mode, A3, pin 2 is held low, this signal is inverted by A7 which then enables A6 pins 1 and 5.

Signal from S3 are now inverted by A8 pins 3 and 4, and again by A6 pins 3 and 4. These levels control the - SOURCE ENABLE and via A7 the + SOURCE ENABLE.

The high from S1g, when S1 is not in the AUTO mode, is inverted by A7 pin 6, the resulting low at A8 pin 8 is inverted at A8 pin 10, which enables K2 relay via Q3 and the INTEGRATOR ENABLE/DISABLE lines via A8 pin 11 and A7 pin 10.

S1c energises the red warning LED, DS1, biased from the negative 15-volt rail by R22.

4.10 POWER SUPPLIES

240-volt 50-Hz mains power is applied to the power transformer, T1, via F1, a 250-mA delayed action (Slo-Blo) fuse, and power switch S6. The secondaries of T1 are connected to give 15 - 0 - 15 volts rms which is applied to two conventional full-wave rectifier circuits. CR12 and CR13 are connected for a positive output which is filtered by C16 and applied to positive three-terminal regulator A16. The +15-volt output is bypassed by C17. The -15-volt circuit is similar, using CR14, CR15, C18, A17 and C19.

The 15-volt supplies drive all circuits in the MCC-1 as well as the two associated MPE-1 units.

DS2, operating from the -15-volt rail via R39, indicates that mains power is on.

4.11 EMERGENCY POWER SUPPLY

The requirement to Generate +/- 14 volt supplies to power the MCC-1 and MPEs during mains failure, is met by a simple oscillator, diode pump circuit, and three terminal regulators, using an external 24 volt D.C. supply.

CR9 provides protection for the emergency supply in event of the external D.C. being applied with incorrect polarity.

A2, a +12 volt regulator, with its common lead held at +2 volt by R1 and R2, provides +14 volts directly from the 24 volt supply.

Since the 24 volt supply cannot be guaranteed due to voltage drop over long wires, the D.C. supply is pre-regulated to +18 volts by A1. The following stages have greater gain to allow for the lower voltage input.

A4 is configured as an astable multivibrator with the output at pin 7, a square wave of 18 volt amplitude, at approx 400Hz, this sqaure wave is coupled to the darlington transistor pairs Q1, Q2 and Q3, Q4. The output at the junction of the emittors of Q2 and Q4 is a square wave of approx 14 volt amplitude.

The square wave applied to diodes CR1-4 and capacitors C1-4 is inverted and doubled. after losses due to diodes etc, approx -22 volts is available at the junction of C4 and CR4.

A3, a -12 volt regulator, with its common lead held at -2 volts by R3 and R4, supplies -14 volts from the -22 volt supply.

When the 15 volt mains powered supplies drop below 14volts, the 14 volt supplies from the emergency power supply, automatically power the MCC-1 and MPEs via CR7 and CR5.

LED, DS1 (yellow), on the front panel indicates the correct operation of the emergency power supply.

4.12 CHASSIS WIRING

Chassis wiring associated with the current source and control logic circuits is incorporated into Schematic Sheets Nos 2 and 2a, in which hard-wiring from chassis mounted components to the printed circuit board is indicated.

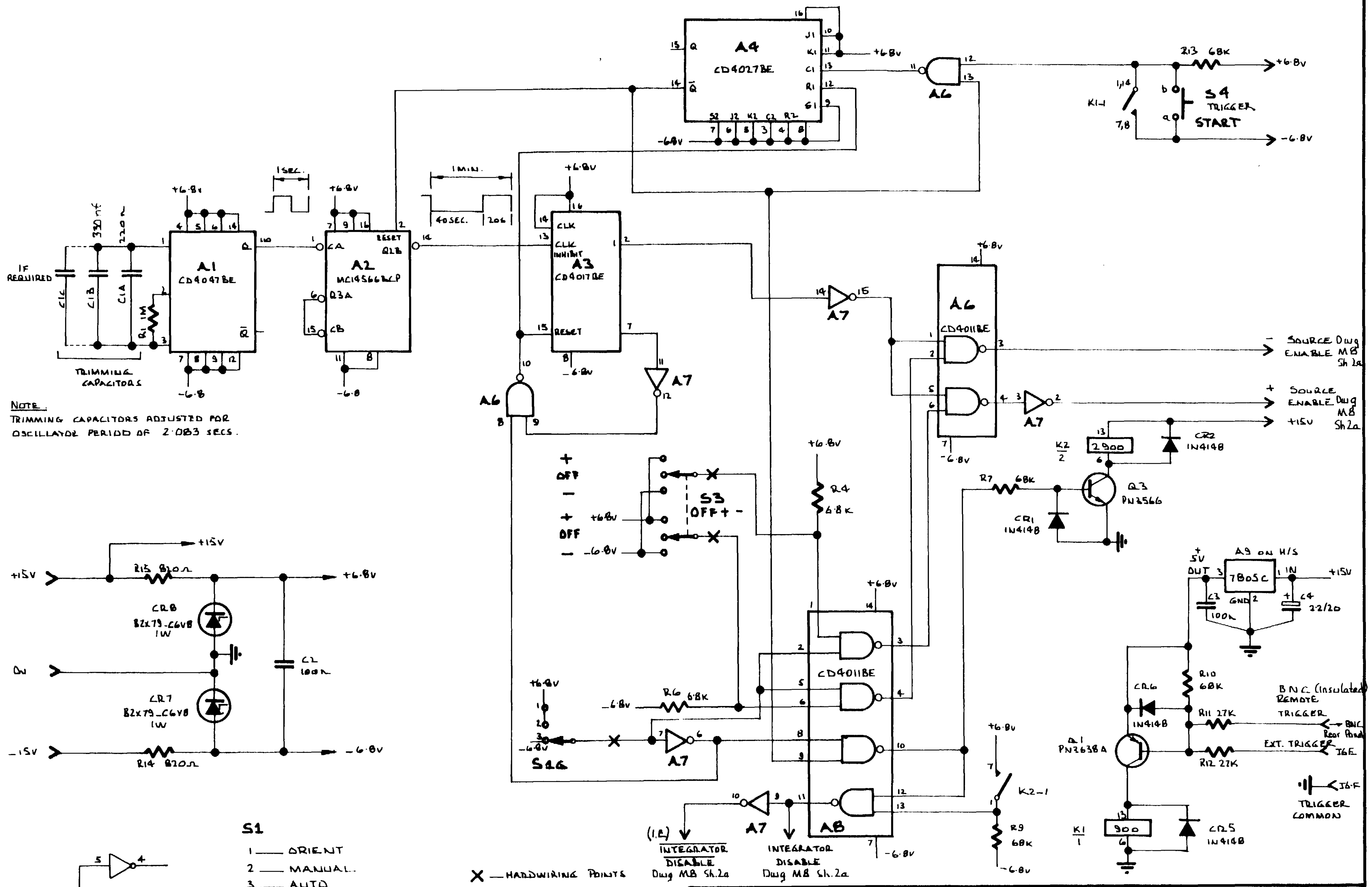
The remaining chassis wiring concerned with interconnection of recorders, MPE-1 units, power and trigger sources is detailed in Schematic Sheet No. 3. These functions are described in Section 3.

Drawn	Date	Checked	Amendments	Issue
[illegible]	6.9.84		ZEDRAWN	1
F.CLEMENTS	16-10-84		Various Designations	2

S1 — SEE SHEET 2a & PARTS LIST

S2, S3 — " D.P. 3 POS. CENTRE OFF
S4 — " 8221 DPDT (PUSH BUTTON)

K1 — ERNIE DILRID – B – 1A 4.5 – 5V } IN SOCKETS
K2 — " " – B – 2A 4.4 – 15V }



Drawing No.	Sheet No.	Title:
MB	2	MCC-1 MAGNETOMETER CONTROLLER SCHEMATIC No 1

Drawn	Date	Checked	Amendments	Issue
	29/11/82			1
	14/12/82		VARIOUS	2
	3/2/83		"	3
	5/10/83		CONNECTIONS TO EMERGENCY SUPPLY INCORPORATED	4
	7.9.84		VARIOUS	5
F.CLEMENTS	16.10.89		DS1.DS2 CCT CHANGES. VARIOUS	6

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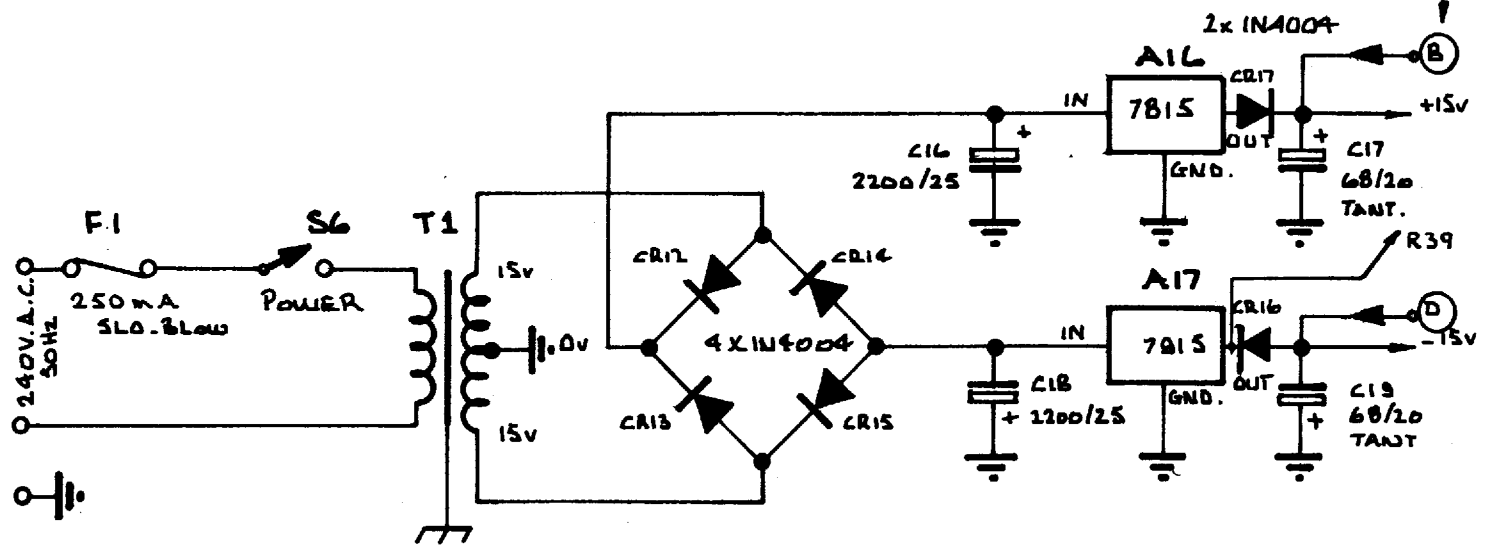
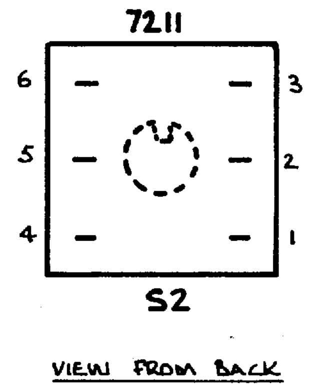
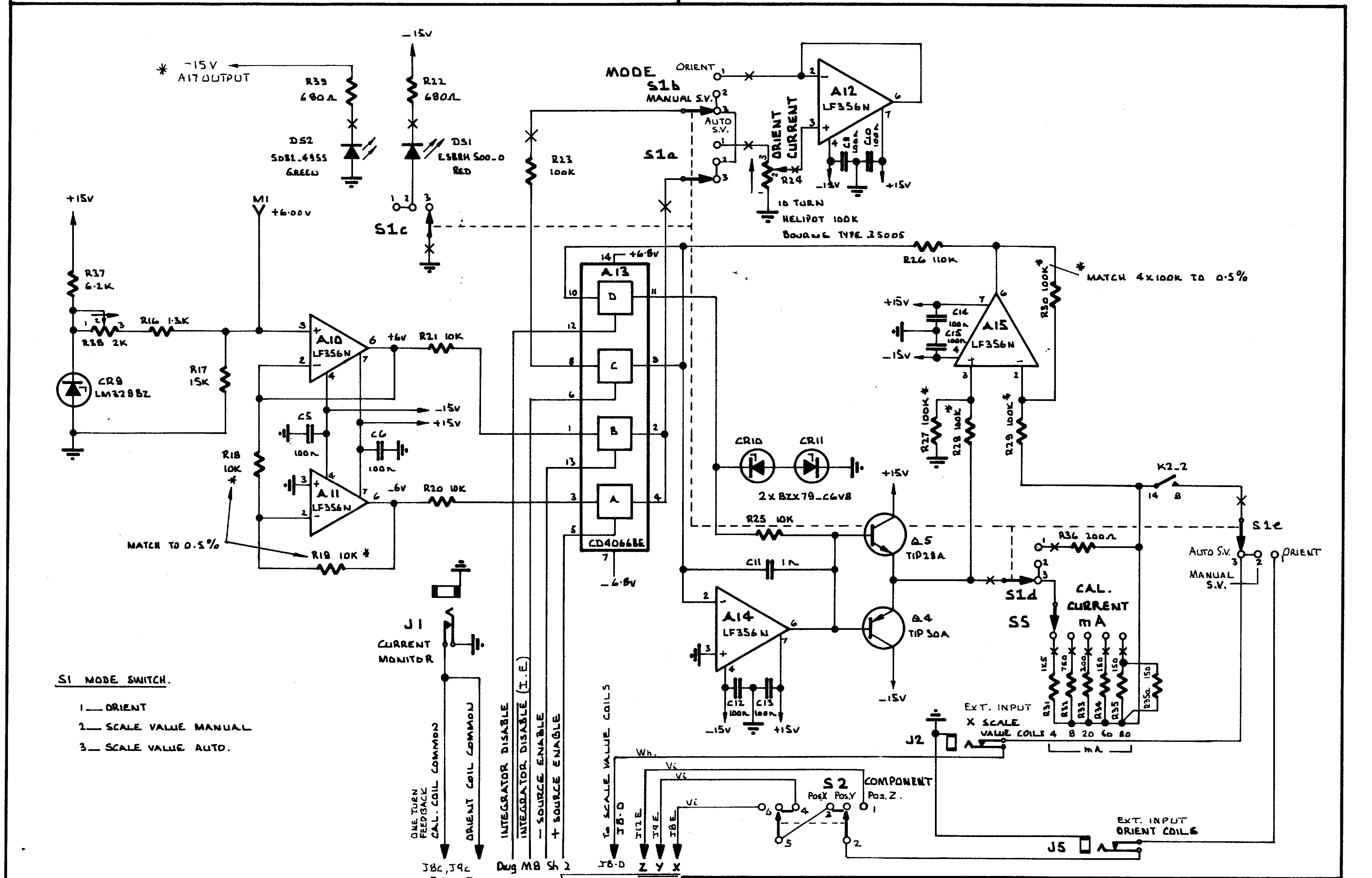


S2 _ SPECIAL SWITCH
CEK 7211 D.P.D.T.





S1 MODE SWITCH.
1 ORIENT
2 SCALE VALUE MANUAL
3 SCALE VALUE AUTO.

X HARDWIRING POINTS.
S.V. SCALE VALUE

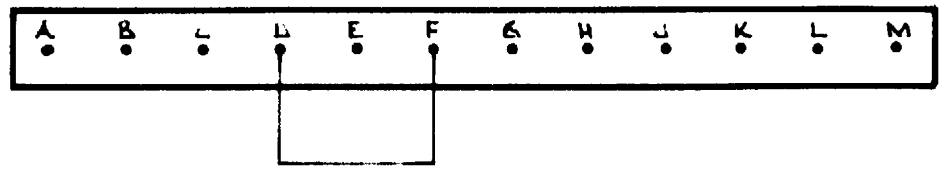
Drawing No.	Sheet No.	Title:
M8	2a	MCC-1 MAGNETOMETER CONTROLLER. SCHEMATIC No 2 / P.S.

R8503909

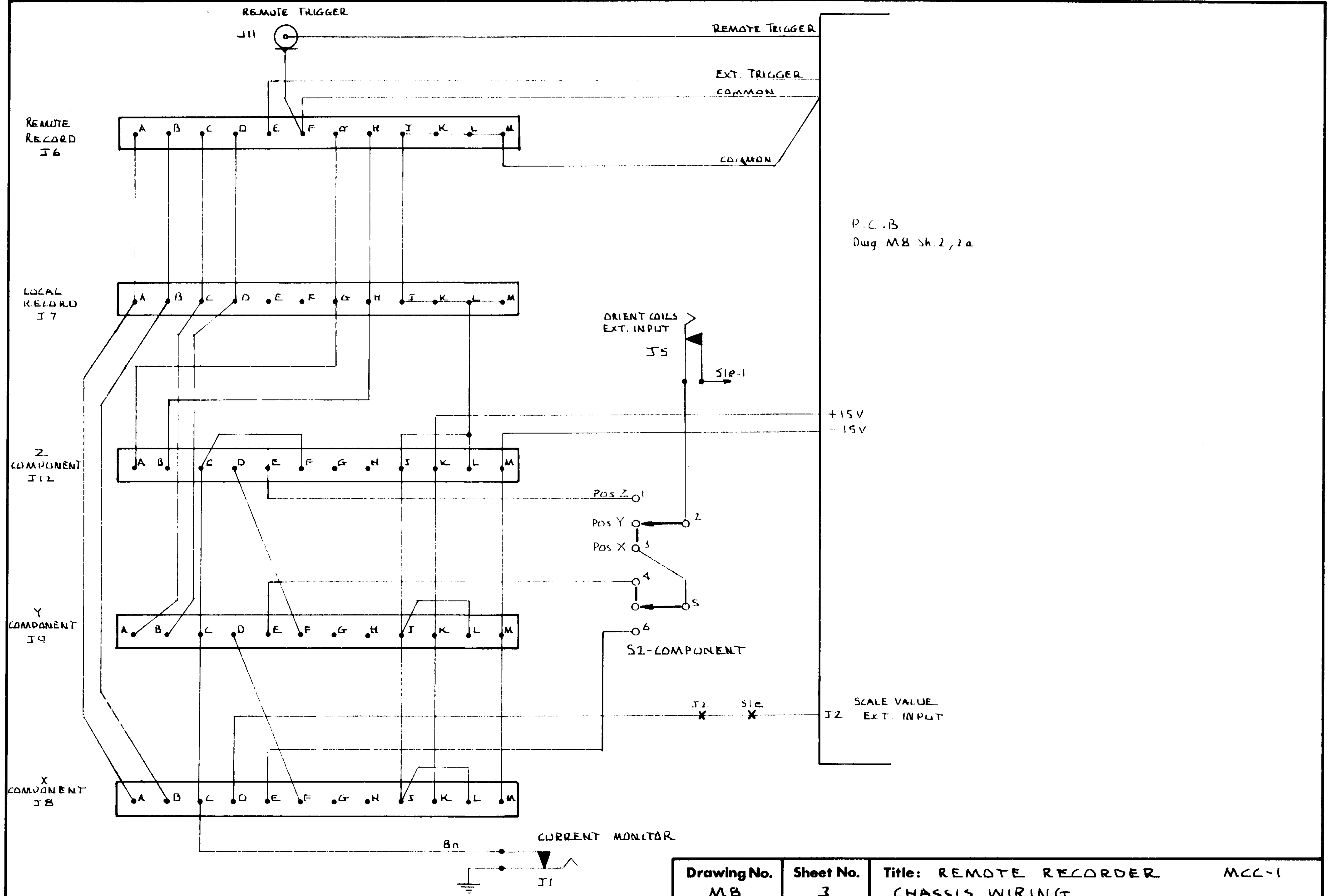
Drawn	Date	Checked	Amendments	Issue
F. CLEMENTS	16-10-84		Dwg M8 Sh 3 Redrawn	1
[illegible]	11-10-85		DUMMY PLUG ADDED	2

BUREAU OF MINERAL RESOURCES, Geology and Geophysics,

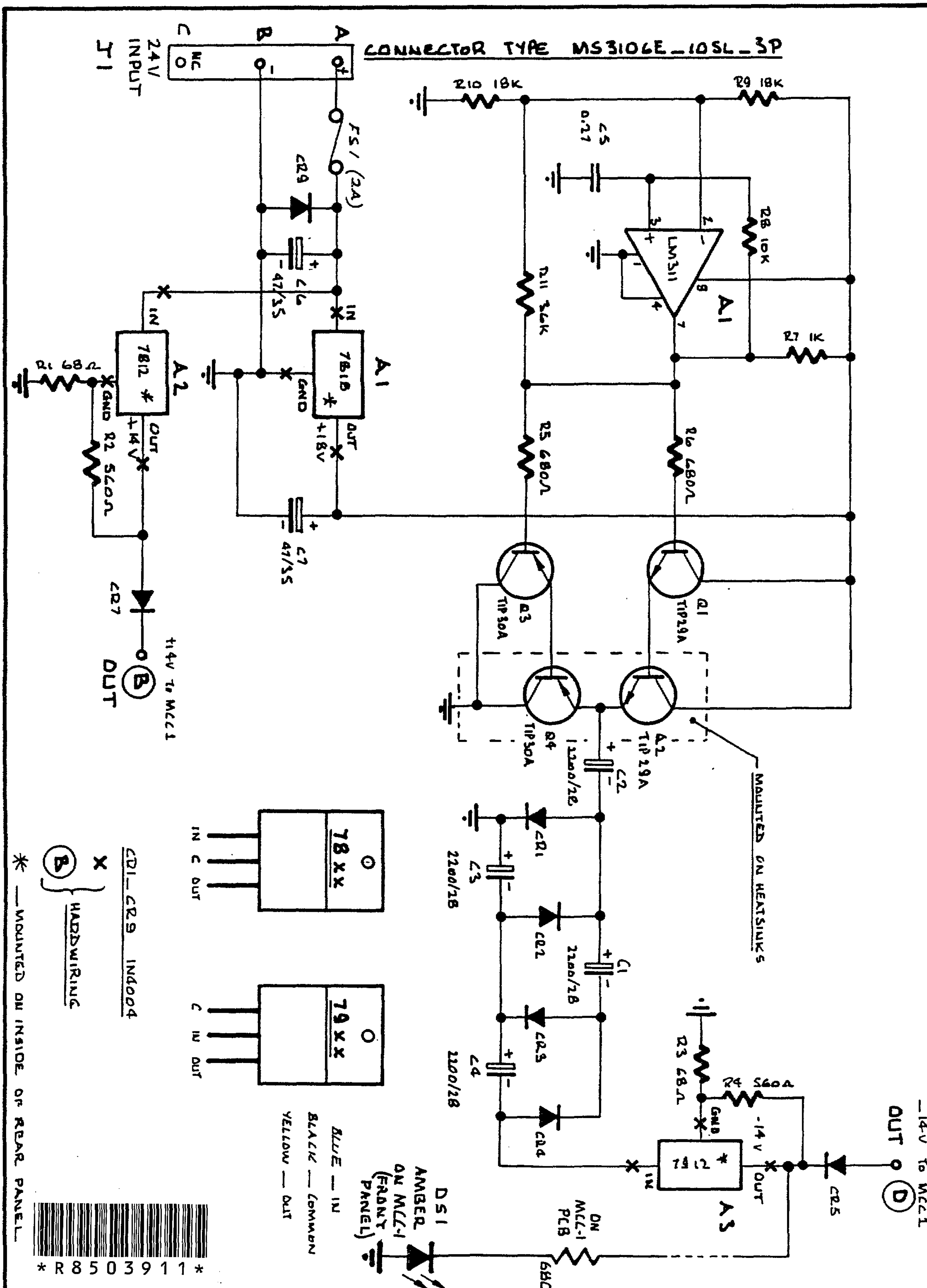
P. O. Box 378, Canberra City, A.C.T. 2601



DUMMY PLUG.



Drawing No.	Sheet No.	Title:
M8	3	REMOTE RECORDER MCC-1 CHASSIS WIRING



Bureau of Mineral Resources, Geology and Geophysics, P.O. Box 378, Canberra City, A.C.T. 2601	Drawing No. M8	Issue	Title:
	Sheet No. 7	3	EMERGENCY SUPPLY
	Drawn [signature] Date 15/10/84		

Item	Value	Vw	Tol %	Type	Make	Maker's Ref	BMR Vocab	Qty
A1	14-PIN	D.I.P		CMOS I.C. MONOSTABLE/ASTABLE MULTVIBRATOR	RCA	CD4047BE	BUC-4047	1
A2	16-PIN	"		CMOS / MSI TIME BASE GENERATOR	MOTOROLA	MC-14566BCP	BUC-4566	1
A3	16-PIN	"		CMOS I.C. DECADE JOHNSON COUNTER	RCA	CD4017BE	BUC-4017	1
A4	16-PIN	"		CMOS I.C. DUAL J-K MASTER-SLAVE F.F.	RCA	CD4027BE	BUC-4027	1
~~A5~~	~~14-PIN~~	~~"~~		CMOS I.C. ~~TRIPPLE 3-INPUT NOR GATE~~	~~RCA~~	~~CD4025BE~~	~~BUC-4025~~	~~1~~
A6, 8.	14-PIN	"		QUAD 2-INPUT NAND GATE	RCA	CD4011BE	BUC-4011	2
A7	16-PIN	"		HEX BUFFER/CONVERTER, INVERTING	RCA	CD4049UBE	BUC-14049	1
A9				+5V REGULATOR	FAIRCHILD	μA7805UC	N.I.V	1
A10-12, A14, 15.				OPERATIONAL AMPLIFIER	NATIONAL	LF356N	N.I.V	5
A13	14-PIN	D.I.P		QUAD BILATERAL SWITCH	RCA	CD4066BE	BUC-4066	1
A16				+15V REGULATOR	FAIRCHILD	μA7815UC	N.I.V	1
A17				-15V REGULATOR	"	μA7915UC	N.I.V	1
HEATSINKS FOR				A16, A17 EACH USES ½ OF :-	DICK SMITH	H-3401	N.I.V	1
SOCKETS	8-PIN	D.I.L		FOR A10-12 14, 15.	UTILUX	SERIES SO	BHS-39	5
	14-PIN	"		FOR A1, 6,8,13.	"	"	BHS-40	4
	16-PIN	"		FOR A2-4, 7.	"	"	BHS-44	4
CR1, CR2 CR4, CR6				SILICON DIODE	PHILIPS	IN4148	BVD-IN4148	4
CR7, 8, CR10, 11.	6.8v 5mA			SILICON ZENER DIODE	"	BZX79-C6V8	BVD-3068	4
CR9	6.9v		5%	VOLTAGE REFERENCE DIODE	NATIONAL	LM329BZ	N.I.V.	1
CR12, CR15, CR16, CR17	400P.I.V	1A		RECTIFIER DIODE	PHILIPS	IN4004	BVD-IN4004	4
DS1				L.E.D., RED	STANLEY	ESBRH-500-0	N.I.V	1
DS2				L.E.D., GREEN	HEWLETT PACKARD	5082-4955	BVA-4955	1
MOUNTING CLIP & RING				FOR DS1, DS2.	"	5082-4707	BVA-PC4707	2

Bureau of Mineral Resources, Geology and Geophysics, P.O. Box 378, Canberra City, ACT 2601	**Instrument :** MCC-1 PHOTO-ELECTRONIC MAGNETOMETER CONTROLLER	COMPONENTS COMPOSITE
		SHEET No. M8/2(i) ISSUE 2
	Module: CONTROLLER MCC1	DRAWN KAM DATE 1/2/83

Item	Value	Vw	Tol %	Type	Make	Maker's Ref	BMR Vocab	Qty
Q1				TRANSISTOR, PNP	FAIRCHILD	PN3638A	BVT-PN3638A	1
Q2,				TRANSISTOR, NPN	"	PN3566	BVT-PN3566	1
Q4				TRANSISTOR, PNP	"	TIP 30A	BVT-TIP30A	1
Q5				TRANSISTOR NPN	"	TIP29A	BVT-TIP29A	1
C1B	330nF	100	10	CAPACITOR CERAMIC VP	VIT.	VP23BY 334 KB	BCA_1334	1
C1	220n	100	10	CAPACITOR, CERAMIC, VP	VITRAMON	VP23BY 224KB	BCA-1224	1
C2, 3, 5, C6, 9, 10.	100n	100	10	CAPACITOR, CERAMIC, VP	"	VP22BY 104KB	BCA-1104	6
C12-15	100n	100	10	CAPACITOR CERAMIC VP	"	"	"	4
C4	2.2μF	20	10	CAPACITOR, ELECTROLYTIC, CSR-13	SPRAGUE	CSR13E 225KL	BCK-03225	1
C16, 18.	2200μF	25	+50 -10	CAPACITOR, ELECTROLYTIC, ALUMIN.	SIEMENS	B41-010 C5228-T	BCE-04228	2
C17, 19.	100μF	20	10	CAPACITOR, TANTALUM	SPRAGUE	CS13BE-686K	N.I.V.	2
C7, 8,	—			NOT IN CIRCUIT				
C11	1nF	100	10	CAPACITOR CERAMIC V.P.	VIT.		BCA_1102	1
R1	1MΩ	0.5	2	RESISTOR, TIN OXIDE	WELWYN	MRS	BRB-56105	1
R4, 6, 9, 10, 7, 13.	68k	0.4	2	RESISTOR, METAL FILM, MR25.	PHILIPS	2322-151 46803	BRA-55683	6
R8, 11, 12.	27k	0.4	2	RESISTOR, " " "	"	... 42703	BRA-55273	3
R14, 15.	820Ω	0.4	2	RESISTOR, " " "	"	... 48201	BRA-55821	2
R16	1k3	0.4	2	RESISTOR, " " "	"	... 41302	BRA-55132	1
R17	15k	0.4	2	RESISTOR, " " "	"	... 41503	BRA-55153	1
R18, 19.	10k	0.4	2*	* MATCHED PAIR 0.5% RESISTOR, " " "	"	... 41003	BRA-55103	2
R20, 21, 25.	10k	0.4	2	RESISTOR, " " "	"	... 41003	BRA-55103	3
R22, 39	680Ω	0.4	2	RESISTOR, " " "	"	... 46801	BRA-55681	2
R23	100k	0.4	2	RESISTOR, " " "	"	... 41004	BRA-55104	1
R24	100k			POTENTIOMETER, HELIPOT, 10-TURN	BOURNS	3500S-2-104	N.I.V	1
				KNOB, TURNS COUNTING,	BECKMAN	2606	BHK-40	1

Bureau of Mineral Resources, Geology and Geophysics, P.O. Box 378, Canberra City, ACT 2601	**Instrument:** MCC-1 PHOTO-ELECTRONIC MAGNETOMETER CONTROLLER	COMPONENTS COMPOSITE; SHEET No. M8/2(ii); ISSUE 2
	Module: CONTROLLER MCC1	DRAWN KAM; DATE 1/2/83

1980 A

Item	Value	Vw	Tol %	Type	Make	Maker's Ref	BMR Vocab	Qty
R26	110k	0.4	2	RESISTOR, METAL FILM, MR25.	PHILIPS	2322-151 41104	BRA-55114	1
R27-30	100k	0.4	2*	RESISTOR, " " " MATCHED TO 0.5%	"	... 41004	BRA-55104	4
R31	1k5	0.4	2	RESISTOR, " " "	"	... 41502	BRA-55152	1
R32	750Ω	0.4	2	RESISTOR, " " "	"	... 47501	BRA-55751	1
R33	300Ω	0.4	2	RESISTOR, " " "	"	... 43001	BRA-55301	1
R34, R35, 35a.	150Ω	0.4	2	RESISTOR, " " "	"	... 41501	BRA-55151	3
R36	200Ω	0.4	2	RESISTOR, " " "	"	... 42001	BRA-55201	1
R37	6k2	0.4	2	RESISTOR, " " "	"	... 46202	BRA-55622	1
R38	2k	0.5	85°C	TRIMPOT, PALARIUM ELEMENT, 25-T.	BOURNS	3282L	BPC-3202	1
F1	250mA			FUSE, 3AG, SLO-BLO.			BFC-1251	1
				FUSE HOLDER.	BELLING & LEE	L1348	BFX-1	1
J1, J2, J5.				PHONE JACK, TIP & SLEEVE WITH NORMALLING CONTACT	EQUIV. TO BULGIN	J12	N.I.V	3
K1	900Ω			RELAY, D.I.P	ERNIE	DILRID-B-1A4.5-5-10L42	N.I.V	1
K2	2900Ω			RELAY, D.I.P	"	DILRID-B-2A4.5-15-20L46	N.I.V	1
~~K3~~	~~700Ω~~			~~RELAY, D.I.P~~	"	DILRID-B-2W4.3-15-60L14	~~N.I.V~~	~~1~~
				SOCKETS, FOR K1 – K3, 14-PIN	UTILUX	SERIES SO	BHS-40	2
S1				SWITCH, 3 SECTION, 3 POLE, 3 POSITION. BREAK BEFORE MAKE.	N.S.F	TYPE A	BSW-33	1
S2, S3				SWITCH, D.P.D.T.	C & K	7203	BST-6	2
~~S3~~				~~SWITCH, DPDT, (SPECIAL)~~	~~C & K~~	~~7211~~	~~N.I.V~~	~~1~~
S4				SWITCH, DPDT	C & K	8221	BSP-8	1
				CAP, RED.	C & K	7089	"	1
S5				SWITCH, ROTARY, 1 POLE, 12 POS. BREAK BEFORE MAKE, STOP AT 5TH POSITION	LORLIN	TYPE RA	BSW-111	1
S6				SWITCH, SPDP, A.C. POWER.	C & K	7101SYZQ	BST-22	1
T1				TRANSFORMER, 240VAC/15v-CT-15v	FERGUSON	PL30/20VA	N.I.V	1

Bureau of Mineral Resources, Geology and Geophysics, P.O. Box 378, Canberra City, ACT 2601	**Instrument :** MCC-1 PHOTO-ELECTRONIC MAGNETOMETER CONTROLLER	COMPONENTS COMPOSITE
		SHEET No. M8/2(iii) ISSUE 2
	Module: CONTROLLER MCC1	DRAWN KAM DATE 2/2/82

1980 A

Item	Value	Vw	Tol %	Type	Make	Maker's Ref	BMR Vocab	Qty
				REAR PANEL HARDWARE				
J6, J7	12-PIN			CONNECTOR, BOX MTG.	CANNON	KPTO-2E 14-12S	BKF-019	2
J10	3-PIN			RECEPTACLE, 240VAC POWER.	MOLEX	427A	N.I.V	1
J11				CONNECTOR, BNC, INSULATED.	DAGE	4890-1	BKZ-291	1
				CASE, INSTRUMENT.	ELMASET	1482-02	BHM-201	1
J8, J9, J12	19 PIN			CONNECTOR BOX MTG.	CANNON	KPT-02E 14-19-S	BKF-025	3
				CABLING BETWEEN MCC1 AND 3 MPE-1 AND RECORDER.				
	12 PIN			STRAIGHT PLUG	CANNON	KPT-06F 14-12-S	BKF 119	3
	"			" "	"	KPT-06F 14-12-P	BKF 120	5
	19 PIN			" "	"	KPT-06F 14-19-P	BKF-126	2

Bureau of Mineral Resources, Geology and Geophysics, P.O. Box 378, Canberra City, ACT 2601	**Instrument:** MCC-1 PHOTO-ELECTRONIC MAGNETOMETER CONTROLLER	COMPONENTS COMPOSITE
	Module: CONTROLLER MCC1	SHEET No. M8/2(iv) ISSUE 1
		DRAWN KAM DATE 2/2/83

1980 A

Item	Value	Vw	Tol %	Type	Make	Maker's Ref	BMR Vocab	Qty
A1				VOLTAGE REGULATOR		7818	N.I.V.	
A2				" "		7812	"	
A3				" "		7912	"	
A4				VOLTAGE COMPARATOR		LM311H	BUALM311H	1
C1, C2, C3 C4	2200μF	25		ELECTROLYTIC ALUMINIUM	SIEMENS	B41 010 C522B_T	BCE 04228	4
C5	0.27μF			CERAMIC	VIT.	VP23BY 274KB	BCA 1274	1
C6, C7	47 F	35	10%	ELECTROLYTIC TANTALUM	SPRAGUE	CSR13F 476KL	BCK 04476	2
FS1	2 AMPS.			FUSE TYPE 3AG.			BFC 202	1
CR1_CR9				SILICON RECTIFIER IN4004			BVD IN4004	9
Q1, Q2				TRANSISTOR SILICON NPN			BVT TIP29A	2
Q3, Q4				" " PNP			BVT TIP30A	2
R1, R3	68Ω		2%	0.4W. METAL FILM MR25	PHILIPS		BRA 55680	2
R2, R4	560Ω		"				BRA 55561	2
R5, R6	680Ω						BRA 55681	2
R7	1K						BRA 55102	1
R8	10K						BRA 55103	1
R9, 10	18K						BRA 55183	2
R11	36K						BRA 55363	1
				CONNECTOR MS3106E_10SL_3P	CANNON		BKA 43	1
				CONNECTOR MS3102E_10SL_3S	"		BKA 33	1
HEATSINK					DICK SMITH	H_3401	N.I.V.	1

Bureau of Mineral Resources, Geology and Geophysics, P.O. Box 378, Canberra City, ACT 2601	**Instrument:** MAG. CONTROLLER	DRG. No. COMPONENTS M8
		SHEET No. 7(i) ISSUE 1
	Module: EMERGENCY SUPPLY	DRAWN [signature] DATE 5/10/83

1980 A