BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

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RECORD

Record 1983/12

HANDBOOKS

for

MPE-1 PHOTO-ELECTRONIC MAGNETOMETER

and

MCC-1 MAGNETOMETER CONTROLLER

by

K. J. Seers

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PREFACE

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.

MPE-1

PHOTO-ELECTRONIC

MAGNETOMETER

K.J. SEERS

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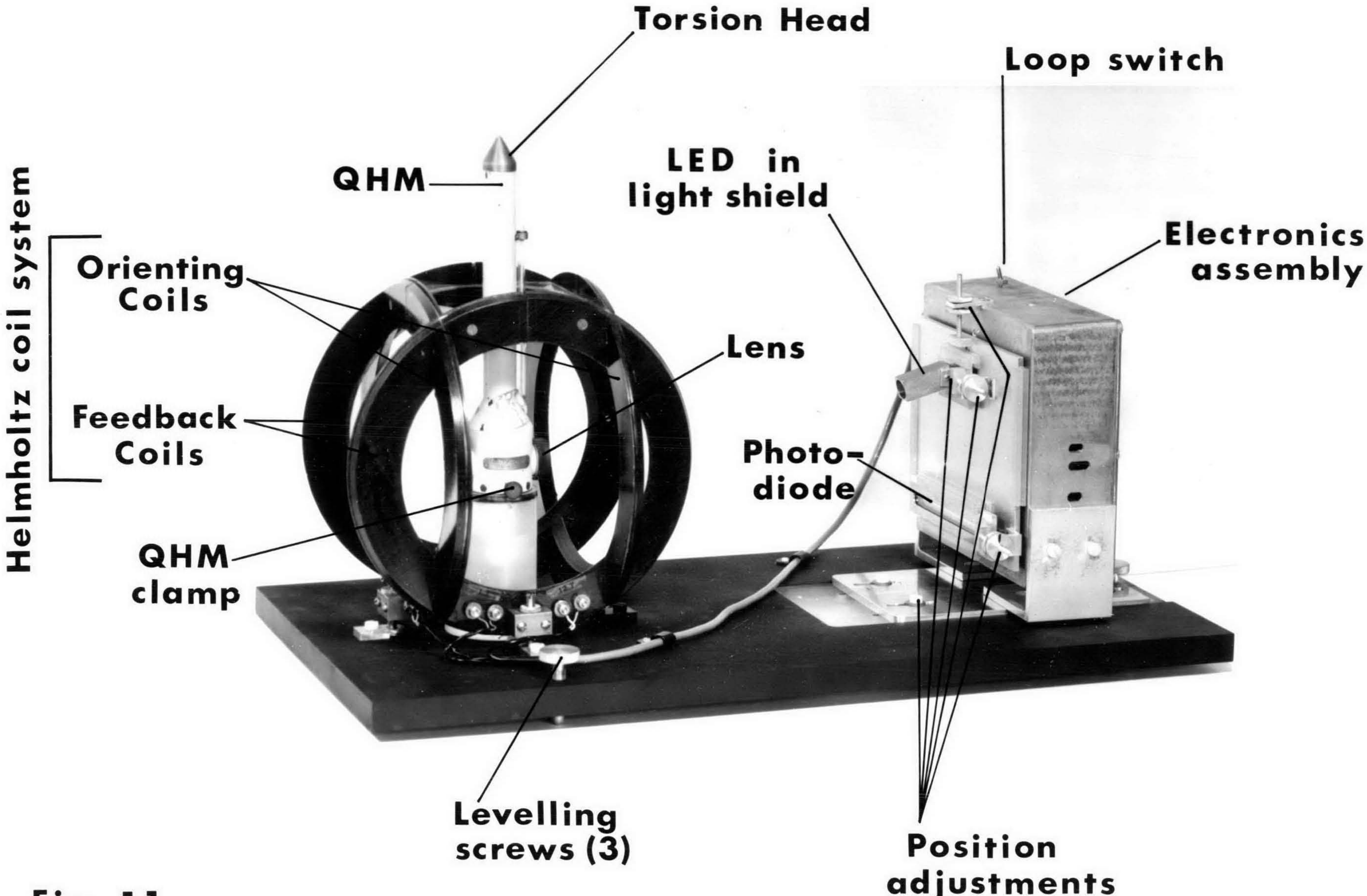

Fig. 1·1

Photograph of MPE-1

GENERAL DESCRIPTION AND PERFORMANCE SPECIFICATIONS

1.1 GENERAL DESCRIPTION

The MPE-1 measures variations in any specified horizontal component of the earth's magnetic field, using a QHM (Quartz Horizontal Magnetometer) in an electronic feedback loop which backs off the variations, thus keeping the QHM magnet in a null position.

The position of the QHM mirror is sensed 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 QHM, thus backing off the field changes. The voltage giving rise to this current is therefore a measure of the field component and forms the output of the MPE-1.

This system has the advantage that QHM magnetometers, 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. The entire system 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 QHM 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 Helmholtz coil system was previously used, for scale-value and orienting functions, with La Cour variometers. The system comprises two orthogonal Helmholtz coils (radius 11.2 cm), each rewound with 12 turns per section. The feedback coil has its axis across the base; the axis of the orienting coil is parallel with the long edge of the base. 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.

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

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

The MPE-1 was entirely designed and constructed in the Engineering Services Branch 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.

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 QHM 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 QHM with natural period T seconds, the MPE-1 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 QHM with natural period T seconds, the 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

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

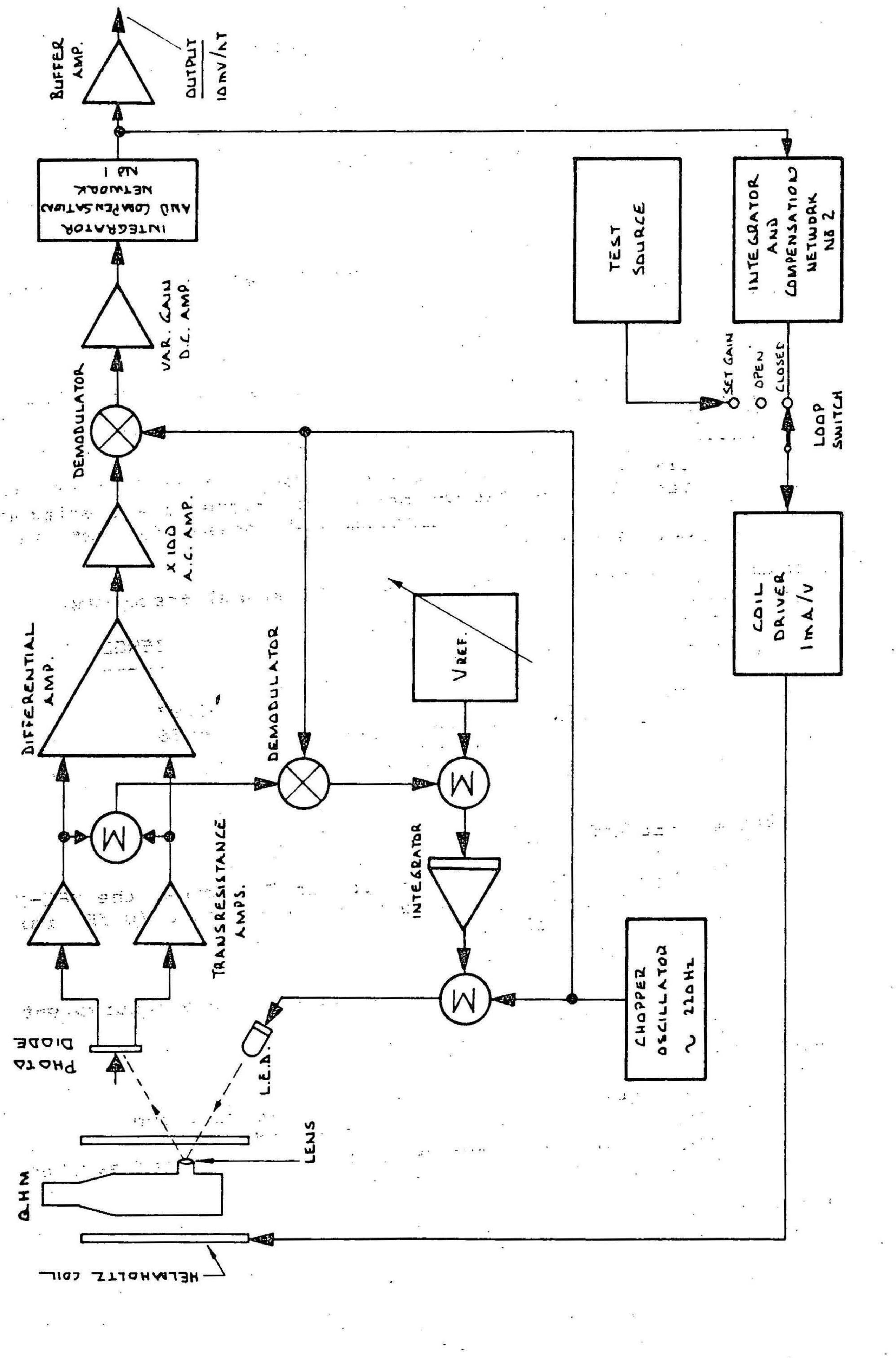

FIG. 2.1 MPE-1 BLOCK DIAGRAM

Bureau of Mineral Resources, Geology and Geophysics, P.O. Box 378, Canberra City, A.C.T. 2601	**Drawing No.** M 8	**Issue**	**Title:** PHOTO ELEC. MAG. BLOCK DIAGRAM.
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	Drawn [signature] **Date** 26/1/82		

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2. BLOCK DIAGRAM DESCRIPTION

Figure 2.1 shows the MPE-1 block diagram.

Light from the light-emitting diode (LED) is chopped at about 220 Hz. The light passes through the lens on the QHM and is reflected by the QHM 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 circuit is enabled at a 220-Hz rate by the chopper oscillator, thus chopping the light beam.

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. After further amplification (by one hundred) in an a.c. coupled 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 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 QHM characteristics.

Analogue output for a chart recorder or for a 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.

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.

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

3. OPERATION

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

Normal practice is to set up the MPE-1 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 MPE-1 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 4.6 for a cautionary note against locating two MPE-1 units where they can interact magnetically or optically.

Section 4 describes in detail the setting-up procedure for the MPE-1. Once this has been done, operation is straightforward. The following precautions should be observed:

1. Do not allow magnetic materials near the MPE-1; they could cause the QHM magnet to flip to the wrong orientation --- see Section 4.6.

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 4.6.

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-1 being detected by the photodiode in the second MPE-1 (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 MPE-1 output will reveal performance abnormalities.

The electronic control loop is not expected to contribute a significant temperature coefficient compared with the known coefficients of QHM magnets. If it is desired to reduce temperature effects, a non-magnetic thermally insulated cover should be carefully placed over the MPE-1 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. 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 two-component system it is more practical to set up both components together than to set up one component completely and then to repeat the whole procedure for the second component.

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, for adjusting QHM torsion
Measuring scale, non-magnetic
White card with vertical black line for observing light spot
Screwdrivers, various sizes
Stopwatch

4.2 HELMHOLTZ COIL SYSTEM

The Helmholtz coils are adjusted for height and levelled with respect to the base during construction. Should re-adjustment ever be necessary, there are adjusting screws (with locking clamps) on each of the four sides of the coil assembly.

To assist with system alignment, the feedback coils are parallel to the longer edge of the base, i.e. their axes are at right angles to this edge. Nominal alignment tolerance is 1/4 degree; this should be checked when initially setting up.

4.3 QHM HEIGHT

The QHM should be transported in its own transit box. To mount it, first undo the single set-screw in the side of the polycarbonate mounting pillar on the MPE-1 base and remove the sliding section. 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.

4.4 OPTICS --- INITIAL SETTING

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.)

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

Check that the four nylon screws which clamp the electronics assembly to the base are located in the rear-most of the three sets 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.

4.5 OPTICS --- COARSE ADJUSTMENT

Using a circular bubble level, ensure that the QHM is vertical by checking and adjusting the levelling of the base. 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.

Connect the MPE-1 to the appropriate channel (X or Y) of the MCG-1 Controller via the cables supplied, and apply power. Ensure that the MPE-1 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 QHM, adjust both the lateral position and the tilt angle of the LED to centre the beam on the QHM lens. Clamp the lateral adjustment. 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 only. 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.

4.6 PRELIMINARY ORIENTATION AND FIBRE TORSIONING

CAUTION

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

1. The units are spaced sufficiently to reduce mutual magnetic interference, from either magnets or 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.

Because the MPE-1 system measures the horizontal magnetic field component at right angles to its longitudinal axis, there are two possible orientations, 180 degrees apart, for measuring a given field component. For each orientation, the outputs for a given field variation will have opposite signs. An orientation convention is therefore necessary and has been defined by the BMR Observatory Section: the QHM end of the base should be to the east to measure X, and to the north to measure Y.

(Note that the QHM mirror has a single central reflective coating on one side, and two strips of reflective coating (top and bottom) on the other side. The axis of the magnet is at right angles to the plane of the mirror (to within 0.5 degrees), and the south-seeking pole of the magnet faces an observer viewing the singly reflective side of the mirror. A reversal of this magnet-mirror relationship would change the orientation convention, because an acceptable light spot is obtained only from the singly reflective side of the mirror which must therefore face the light source and detector.)

Physically orient the MPE-1 by aligning the coil system to the desired direction, following the orientation convention laid down. Level the base as described in Section 4.5, and proceed as follows to torsion the QHM fibre.

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.

Place a white card in front of the photodiode and continue adjusting the torsion until the lateral rest position of the reflected light spot is approximately central with respect to the photodiode. 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.)

4.7 FOCUSING

With the QHM unclamped 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, and move the assembly longitudinally to obtain the best focus. Tighten the screws. Recheck the tilt angle of the LED for maximum illumination on the QHM mirror 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 from behind the QHM.)

4.8 FINAL ORIENTATION

Check that the physical orientation of the system has not been disturbed, and remove all magnetic objects from the vicinity. Switch the MCC-1 Controller to ORIENT and select X or Y channel as appropriate. When the MCC-1 switch labelled '+', 'OFF', '-' is placed in the '+' or '-' position, a d.c. current of up to 30 mA, set by the ORIENT CURRENT potentiometer, flows in the orienting Helmholtz coil, which is orthogonal to the feedback coil. The maximum orienting field available is about 2 500 nT.

Place the white card in front of the photodiode and set the MCC-1 switch to '+'. Note the distance and the direction of the light spot movement. Turn the switch to 'OFF' and adjust the torsion to move the light spot by a small amount in the direction in which it moved in response to the orienting current. Return the switch to '+' and again note the direction and distance of movement. If the movement is in the same direction but the distance is larger, switch to '-' and start again.

Once the correct orienting current polarity is determined, 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.

4.9 LOOP SWITCH FUNCTIONS

These 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 QHM. 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 QHM behaviour. Most, but not all, of the setting-up is done in this mode.

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

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 4.1, to locate components on the printed circuit board. Note that all potentiometer adjustments are accessible through holes in the sides of the electronics housing.

Remove the link between A4 and A5 amplifier stages.

Connect a DMM between M3 and a ground point close to A7 pin 3 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. Adjust R30 for a reading of 0.000 volts.

Turn R32 and R37 fully anticlockwise (minimum resistance). With the loop open, connect the DMM between pins A and B of the output connector J1 (or between point F on the printed circuit board and ground, which is equivalent and may be more accessible). 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.

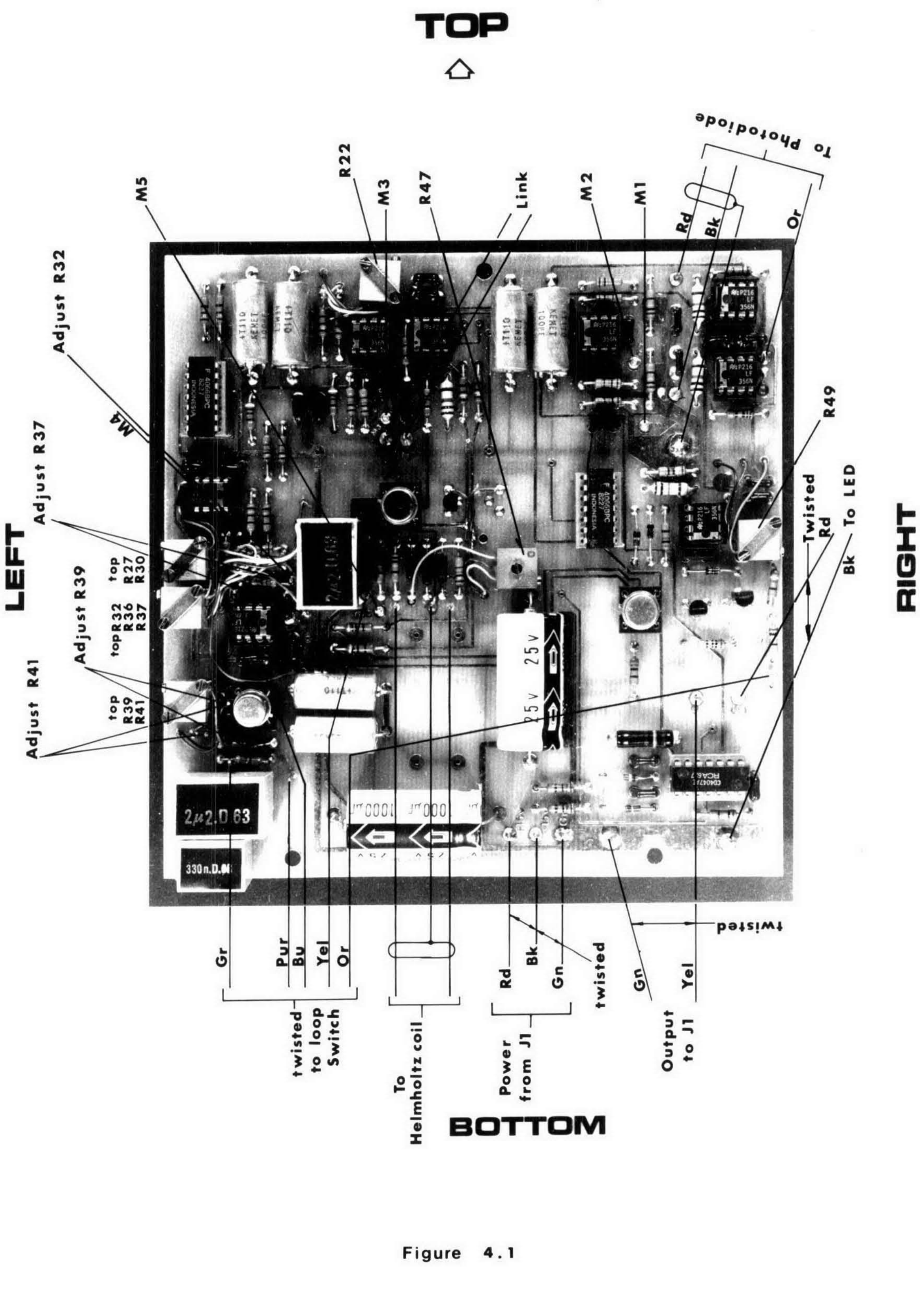

Figure 4.1

PHOTO OF MPE-1 P.C.B.

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:

$$Kh(th) = \{64.\pi/(\sqrt{5})\}.(n/r) \quad nT/mA$$

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 in the MPE-1, n=12 and r is 11.2 cm. Thus,

$$Kh(th) = 96.34 \quad nT/mA, \text{ and}$$

$$|G| = 1.038 \quad mA/V$$

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. Disconnect one lead to the feedback Helmholtz coil (axis transverse to the MPE-1 base) and insert the DMM set to measure current. Set the loop switch to OPEN; 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. Restore the Helmholtz coil lead and return the loop switch to OPEN.

Note that R47 is located near the centre of the printed circuit board. It is therefore advisable to make this adjustment with a screwdriver having an insulated blade.

4.12 COMPENSATION NETWORKS

Measurement of the natural period of the QHM is needed for setting-up the compensation networks. The natural period of a given QHM 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 QHM. 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, must each be adjusted to have a total resistance given by:

Rcomp = 72.34(Tav) kohms

To make the necessary resistance measurements, turn off the power to the MPE-1, 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 4.1). 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 A1 pin 6 and the other channel to A2 pin 6. 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 4.5). 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 for maximum peak-to-peak signal amplitude. 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 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 well away from zero volts, by, say, more than one volt, 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.)

4.15 FEEDBACK AND OUTPUT POLARITIES

Again with the room darkened and with the CRO connected as in the previous section, work firstly on the X unit and 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. If the Helmholtz coil is connected correctly, this movement should be to the left for an observer facing the photodiode, because the X field (the field towards the north) should be reduced by the negative input to the coil driver. If the movement is to the right, reverse the connections at the feedback Helmholtz coil (the 12-turns-per-section coil with its axis transverse to the MPE-1 base).

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; 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 4.1).

The resulting configuration ensures that the feedback will be negative, and that the output will increase positively for a magnetic field change tending to rotate the QHM magnet clockwise when viewed from above (i.e. for an increase in the X field when the X orientation is carried out as per Section 4.6).

Note however that a unit configured as above, and placed in the Y orientation, gives a positive output for field increases towards the west, rather than towards the east. To change the output polarity for the Y unit, reverse both the photodiode and the feedback Helmholtz coil connections (reversing only one of these will result in positive feedback).

To check the feedback polarity, switch the feedback loop to CLOSED. The voltage at M4 should rapidly go to zero 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 QHM magnet.

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

4.16 ESTABLISHING THE REFERENCE OUTPUT

Remove all magnetic material from the vicinity and ensure that the MPE-1 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-1 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.

4.17 SCALE-VALUE TESTS

When an automatic scale-value test is initiated via the MCC-1 Controller, the initial recorder deflection for both the X and the Y components is intended to be positive. If this is not so, reverse the connections at the appropriate scale-value coil.

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, use a screwdriver with an insulated blade to adjust R47, keeping the loop closed.

4.18 INSULATING COVER

If a thermally insulating cover or light shield is to be used (see Section 3), place it over the MPE-1, taking care not to disturb the orientation.

This concludes the setting-up procedure.

5. CIRCUIT DESCRIPTION

Refer to the schematic diagram, MPE-1 Sheet No. 1.

5.1 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. It is operated in the photoconductive mode, i.e. into a low resistance which, in this case, 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 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.

5.2 OPTICAL CONTROL LOOP

The optical control loop maintains constant optical "gain", regardless of aging or replacement of the LED or the photodiode. 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). 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.

5.3 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. 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.

5.4 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 5.2. 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.

5.5 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) V-dc/V-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 4.14.

C20 is included to ensure the stability of this amplifier.

5.6 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 unity-gain amplifier A11, type OP07CJ, chosen for its low voltage offset and drift. R57, in series with the output of A11, isolates this amplifier from the capacitance of the recorder cables.

5.7 SECOND COMPENSATION NETWORK

A9 is connected as a unity-gain inverter for d.c. However, 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.

5.8 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.

5.9 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 4.14.

5.10 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.

5.11 POWER SUPPLIES AND LAYOUT

The MPE-1 operates from plus and minus 15 V supplies located in the MCC-1 Controller. Worst-case current demands for one component are 176 mA from the positive supply and 124 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.

5.12 CONNECTORS

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

Drawn	Date	Checked	Amendments	Issue
[signature]	17/9/82		——	1
[signature]	5/10/82		VARIOUS ——	2
[signature]	27/1/83		" ——	3

BUREAU OF MINERAL RESOURCES, Geology and Geophysics,
P. O. Box 378, Canberra City, A.C.T. 2601

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

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	BZY88-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-500-0	N.I.V.	1
CR10				PHOTODIODE, LATERAL EFFECT, 10cm	UNITED DETECTOR TECHNOLOGY	PIN-LSC/4	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.

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P.O. Box 378, Canberra City, ACT 2601

Instrument: MPE-1 PHOTO-ELECTRONIC MAGNETOMETER

Module: MPE1

COMPONENTS COMPOSITE

SHEET No. M8/1(i) ISSUE 1

DRAWN KAM DATE 26/1/83

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	0.5W	85°C	TRIMPOT, PALARIUM ELEMENT, 25TURN.	BOURNS	TYPE 3282L	BPC-3203	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	0.5W	85°C	TRIMPOT, PALARIUM ELEMENT, 25TURN.	BOURNS	TYPE 3282L	BPC-3105	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	0.5W	85°C	TRIMPOT, PALARIUM ELEMENT, 25TURN.	BOURNS	TYPE 3282L	BPC-3504	4
R48	1k8	0.4	2	RESISTOR, METAL FILM, MR25.	PHILIPS	2322-151-41802	BRA-55182	1

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(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	0.5W	85°C	TRIMPOT, PALARIUM ELEMENT, 25 TURN.	BOURNS	TYPE 3282L	BPC-3103	1
R51	270Ω	1W	2	RESISTOR, TIN OXIDE, TR6.	ELECTROSIL	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	1W	70°C	TRIMPOT, WIRE-WOUND, 25-TURN	BOURNS	TYPE 3280L	BPC-2501	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, 1mm Ø, SPACED 5mm.	"	450-3775-01-03-10	BHM-75	1
CONNECTORS FOR FLYING LEADS				LEAD MOUNTING JACK (1mm Ø)	"	450-3367-01-03-00	BHM-71	18
J1	12-PIN			CONNECTOR, BOX MTG, RECEPTACLE.	CANNON	KPT 02E-14-12P	BKF-020	1
J2	6-PIN			CONNECTOR, BOX MTG, RECEPTACLE.	"	KPT 02E-10-6S	BKF-007	1
S2				SWITCH, TOGGLE, 4-PDT.	C&K	7411	N.I.V.	1
(S1)				NOT USED IN CIRCUIT				
SOCKETS	8-PIN	DIL		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

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

Instrument: MPE-1 PHOTO-ELECTRONIC MAGNETOMETER

Module: MPE1

COMPONENTS COMPOSITE

SHEET No. M8/1(iii) ISSUE 1

DRAWN KAM DATE 27/1/83

A

MCC-1 CONTROLLER

MCC-1

MAGNETOMETER

CONTROLLER

K.J. SEERS

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MAGNETOMETER
CONTROLLER
MCC-1
POWER
ORIENT CURRENT
X
Y
ORIENT COILS
COMPONENT
X
Y
MANUAL
ORIENT
AUTO
MODE
OFF
+
-
CURRENT MONITOR
TRIGGER
CURRENT mA
4
8
20
40
80
X
Y
SCALE VALUE

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-1 Photo-electronic Magnetometer. A typical installation comprises two MPE-1 units measuring orthogonal components of the earth's magnetic field (usually X and Y), 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 QHM orientation (see MPE-1 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-1 outputs.

* Independent access to all scale-value and orienting coils via front-panel jacks.

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-1

Plus and minus 15 V (within 5%) at 350 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 " "
X scale-value coil
Y " "

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.

AUTO SCALE-VALUE SEQUENCE: See Figure 1.1

POWER

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

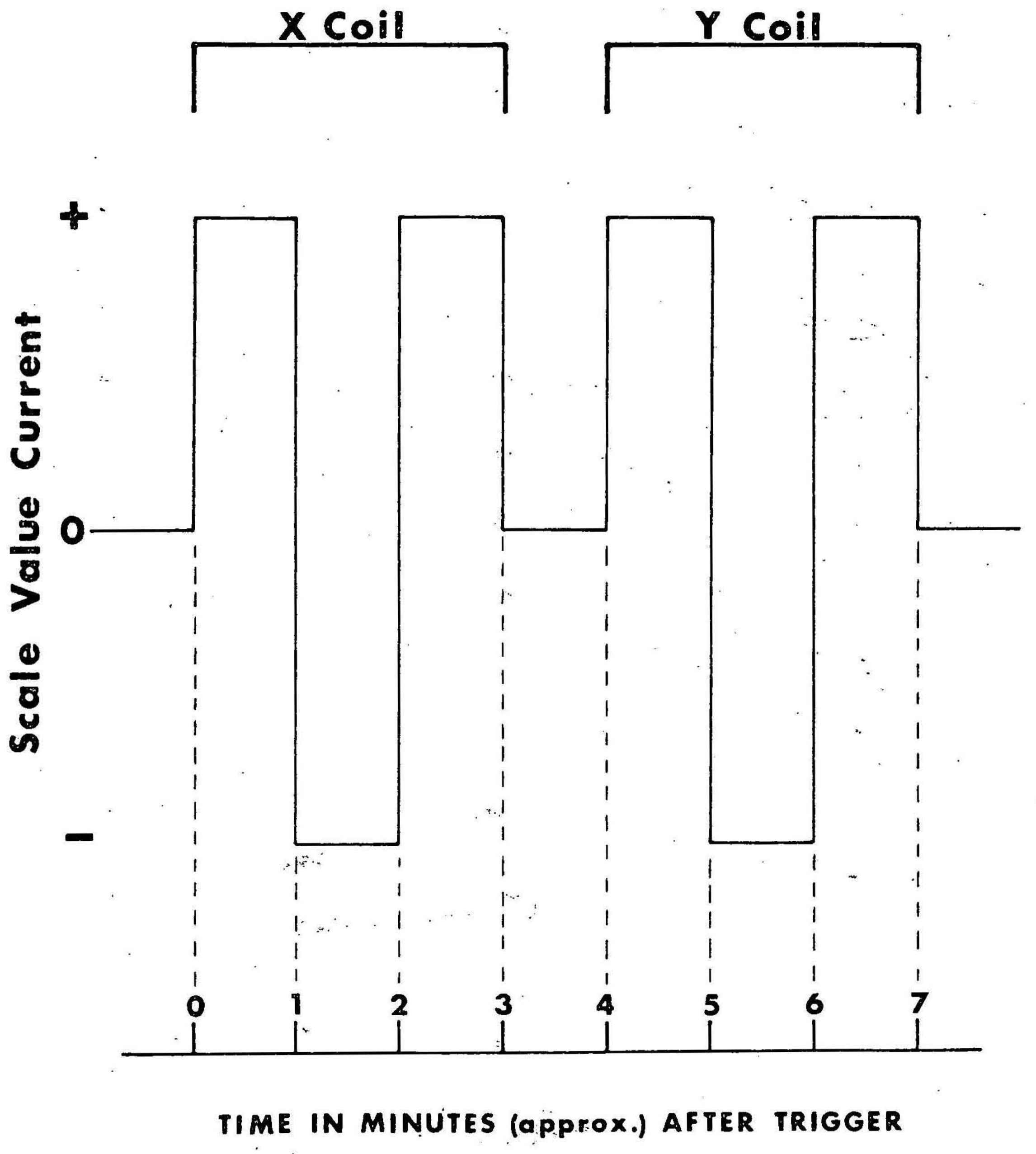


Fig. 1·1

AUTO SCALE-VALUE CURRENT SEQUENCE

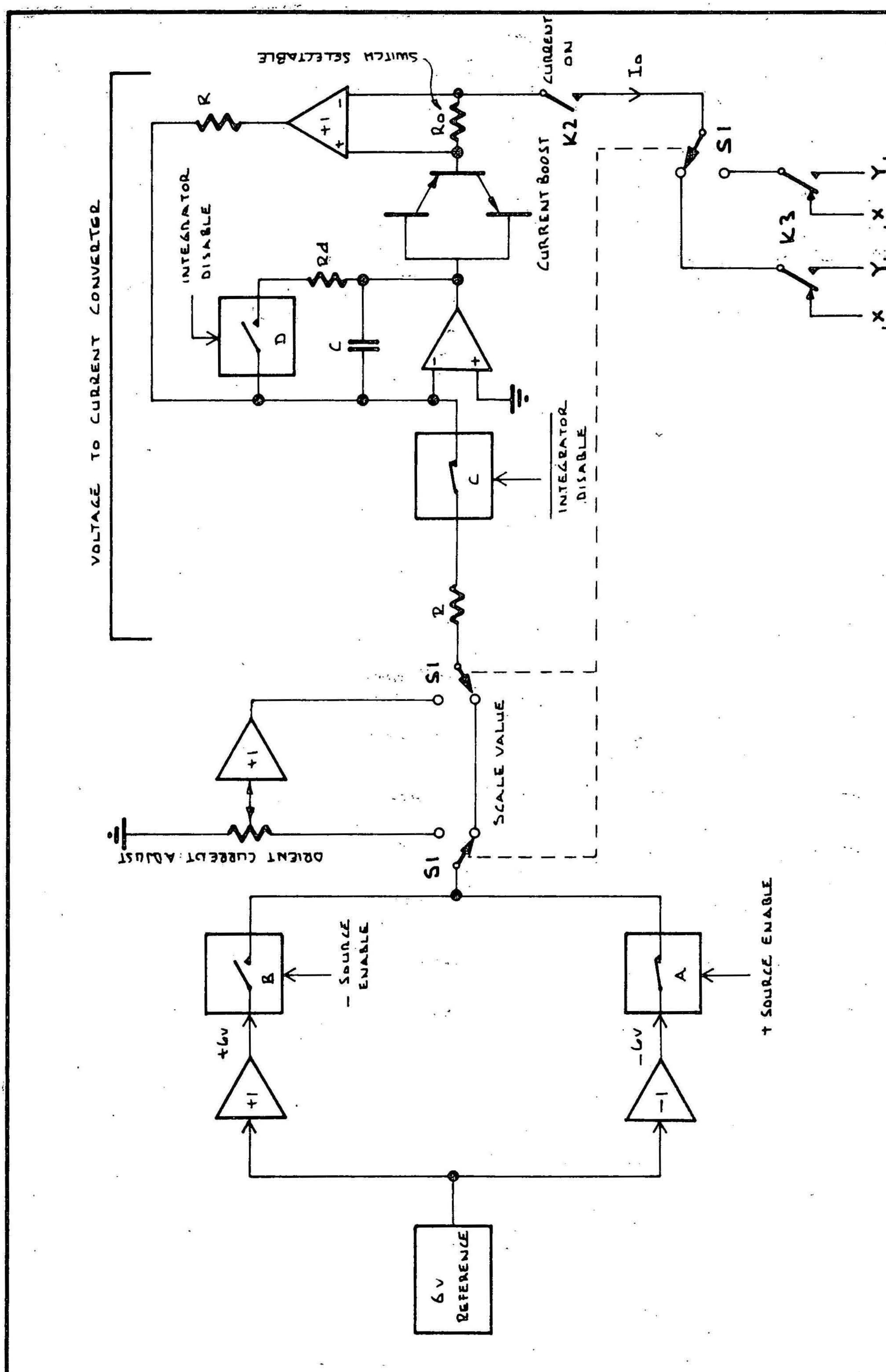


FIG. 2.1 BLOCK SCHEMATIC OF CURRENT SOURCE

Bureau of Mineral Resources, Geology and Geophysics,	Drawing No. M8	Issue	Title: MCC-1
	Sheet No. 6	1	BLOCK SCHEMATIC OF CURRENT SOURCE
P.O. Box 378, Canberra City, A.C.T. 2601	Drawn [signature] Date 4/2/83		

1980 B

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 and K3 (also operated by the control logic) to the selected X or Y scale-value or orient coil.

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 one minute. 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 and ORIENT positions of S1, the manual override logic inhibits 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-1 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 MANUAL and ORIENT modes a second toggle switch selects the X or the Y MPE-1. 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 or ORIENT position.

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

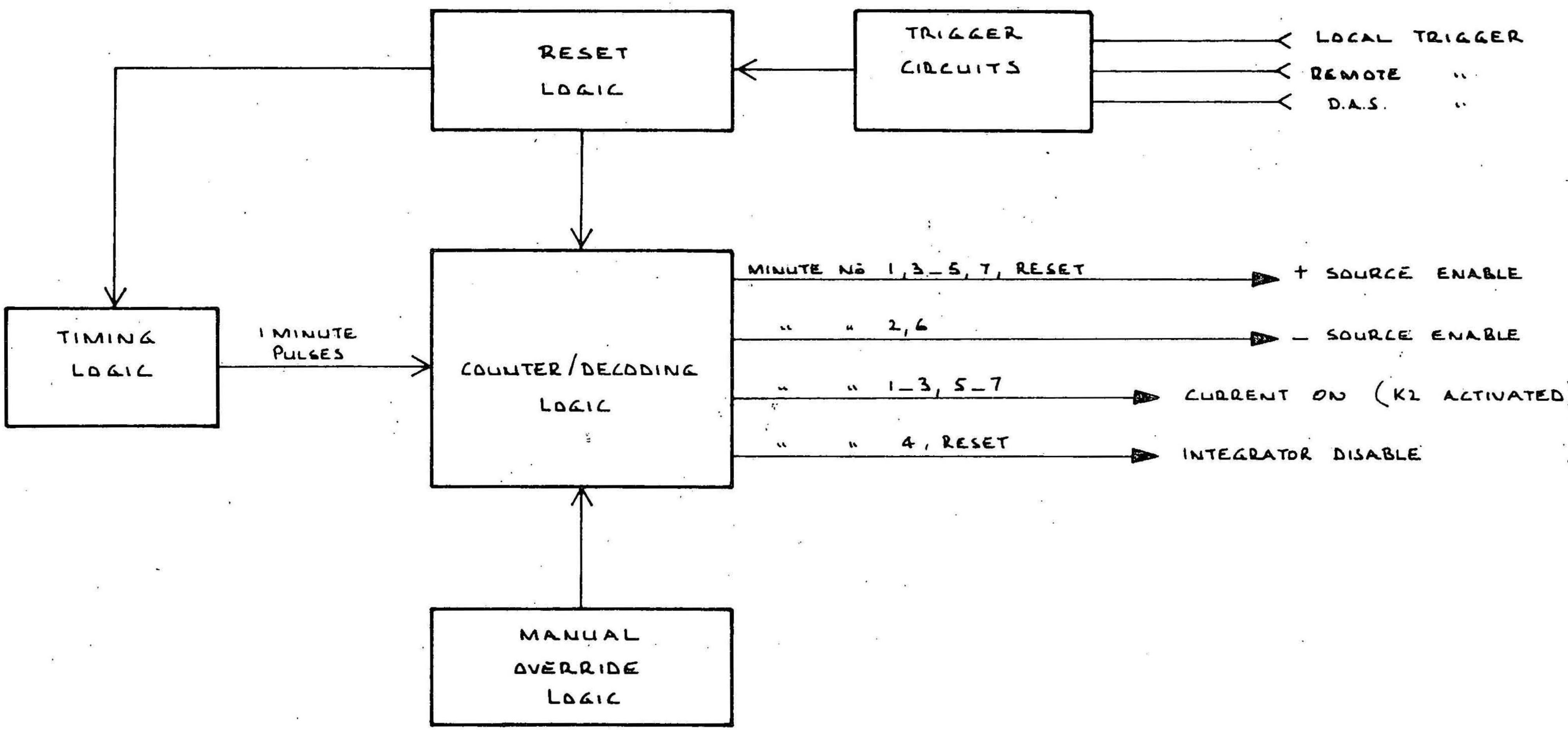


FIG. 2·2 <u>BLOCK DIAGRAM OF CONTROL LOGIC</u>

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 MPE-1 units are supplied. Refer to J8 and J9 on Schematic Sheet No. 3 for connector pin numbers. All connectors are labelled on the rear panel.

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, J2-5 (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 or Y, 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.

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

In the ORIENT position, orienting current is fed to either the X or the Y 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 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 either the X or the Y scale-value coil --- again with the X or Y selection and 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 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 to 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).

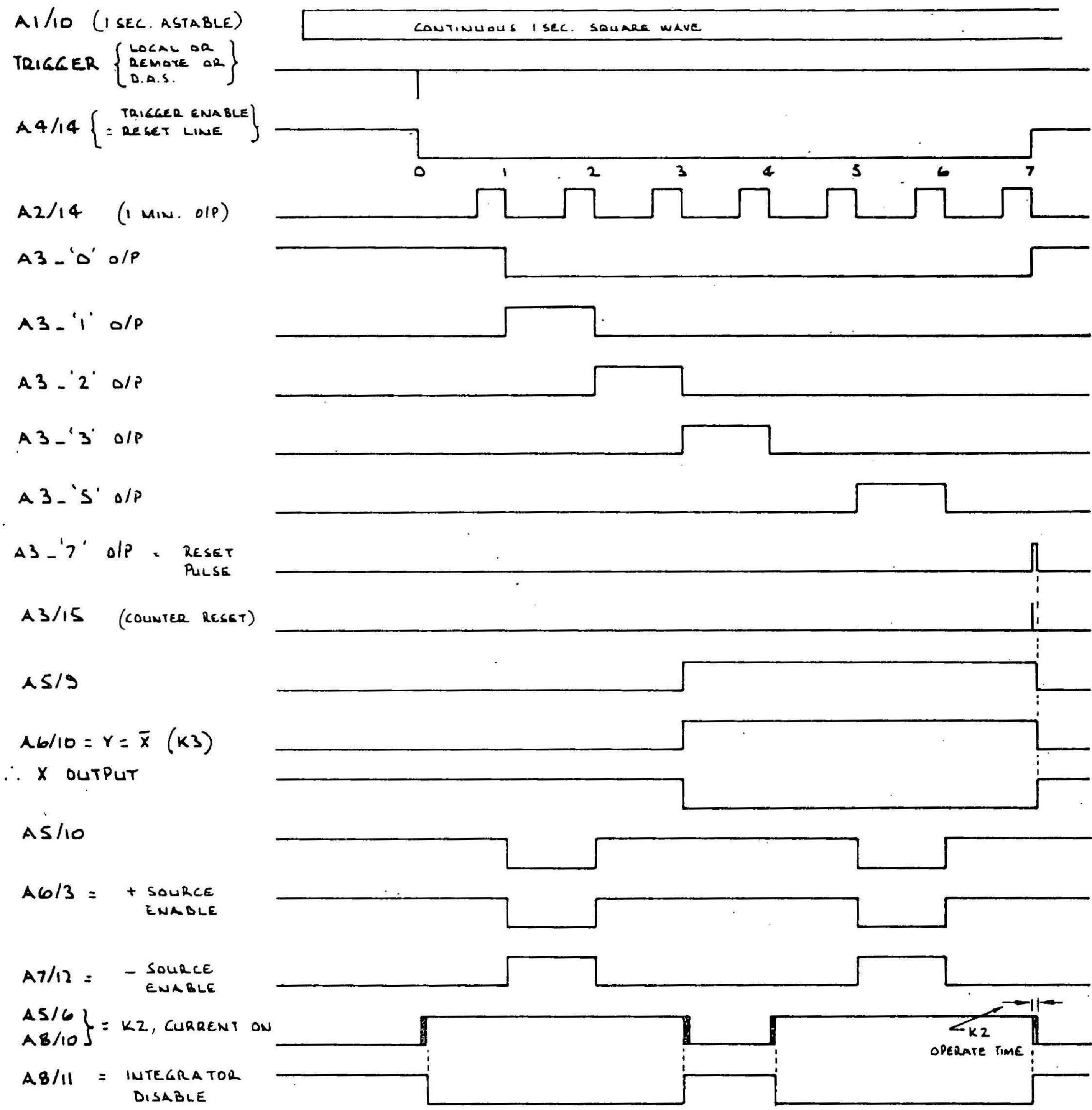
J1 is a similar phone jack in the common line for all coils. A meter connected to a phone plug inserted in J1 can thus monitor the MCC-1 output current.

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

S1. POS. 5 (SCALE VALUE AUTO.)

S2, S3 DON'T CARE



SEQUENCE

1 TRIGGER STARTS 7 MINUTE TIMING SEQUENCE. TRIGGER SOURCE DISABLED. K2 IS TURNED ON, CONNECTING THE +VE CURRENT SOURCE TO THE X CALIBRATE COIL TILL END OF MINUTE No 1.

2 AT END OF MINUTE No 1 CURRENT SOURCE CHANGES FROM +VE TO _VE

3 " " " " No 2 " " " " _VE TO +VE

4 " " " " No 3 INTEGRATOR IS DISABLED (TURNING CURRENT OFF BEFORE K2 OPENS.) K2 OPENS TILL END OF MINUTE No 4. ALSO, K3 OPERATES, CHANGING LOAD TO Y COIL.

5 " " " " No 4 K2 CLOSES, ENABLING INTEGRATOR TO DRIVE +VE CURRENT INTO Y COIL TILL END OF MINUTE No 5

6 " " " " No 5 CURRENT SOURCE CHANGES FROM +VE TO _VE

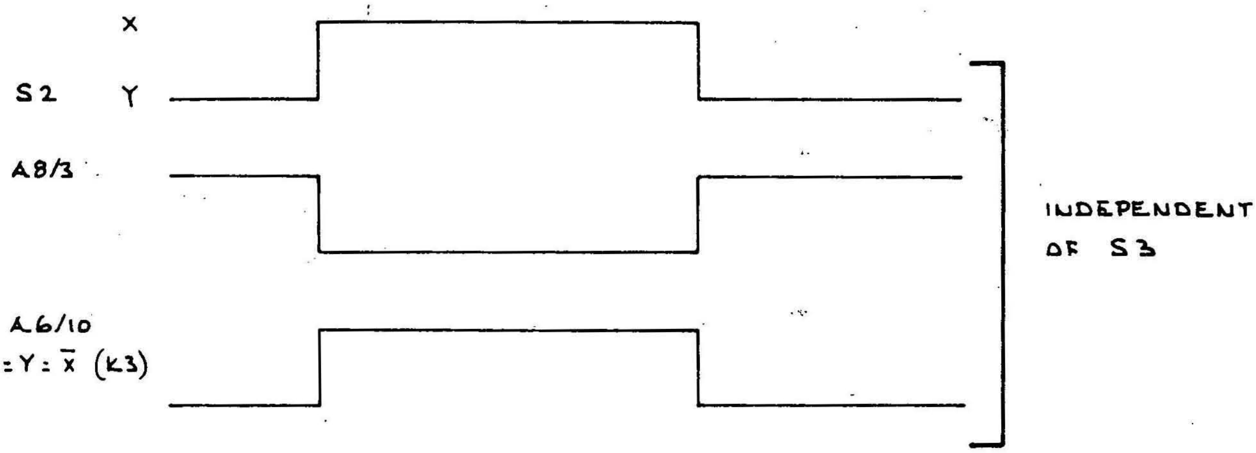
7 " " " " No 6 " " " _VE TO +VE

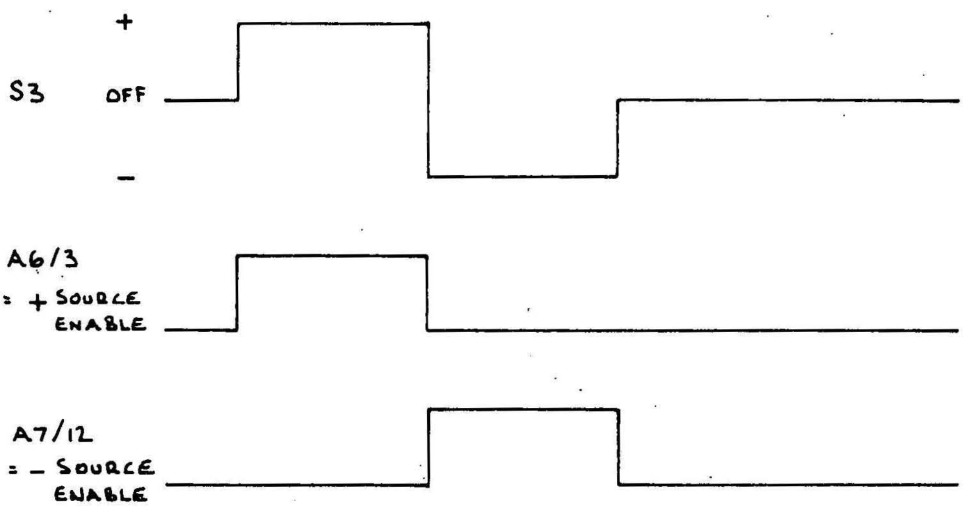
8 " " " " No 7 RESET PULSE INTEGRATOR DISABLED, K2 OFF. K3 OFF (CHANGES LOAD BACK TO X COIL.)

FIG. 4.1 LOGIC DIAGRAM _ AUTO. OPERATION

S1: Pos. 2 (SCALE VALUE MANUAL) COUNTING LOGIC IS RESET BY S1c
(NOTE DIAGRAM IS IDENTICAL FOR S1 Pos. 1 (ORIENT) — OUTPUT CURRENT GOES TO ORIENT INSTEAD OF SCALE VALUE COILS VIA S1c)

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.

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 one second set by R1 and C1. The resulting 1-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 one minute. 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., minute pulses received.

In the AUTO mode, two inverters in A7 cause A3 to reset immediately after the seventh 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 seventh minute when the '7' output of A3 goes HIGH momentarily and resets A4 via S1i. Two inverters in A7 insert a short time delay for resetting A3 via S1h, so giving a very short '7' output pulse.

4.8 COUNTING AND DECODING LOGIC

After the trigger has been accepted, A3 begins to count the one-minute pulses which are decoded and fed to NOR gates in A5. Here the time combinations necessary to perform the sequence of Figure 1.1 are decoded.

When any of the '0' (RESET), '1', or '2' outputs of A3 is HIGH, A5 pin 9 is LOW; for all other combinations, A5 pin 9 is HIGH. After two inversions (in gates of A8 and A6 which are enabled by the manual override logic) this signal drives Q2 which activates relay K3 when A5 pin 9 is HIGH. In its non-activated state, K3 selects the X set of coils; the Y set is selected when K3 is activated. Thus the X coils are connected from the RESET state until the end of the third minute, and the Y coils are connected from the end of the third minute until the end of the seventh minute when the RESET state is again imposed.

When either the '1' or the '5' output of A3 is HIGH, A5 pin 10 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 at all times other than during the second and sixth minutes. The - SOURCE ENABLE signal is derived from the same logic but is inverted by one section of A7, and so it is HIGH only during the second and sixth minutes.

During the RESET state or when the '3' output of A3 is HIGH, A5 pin 6 is LOW, and thus A7 pin 2 is HIGH. This signal 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 and during the fourth minute.

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 three and five to seven, 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 start of the fourth minute and on 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, S1h ensures that A2, the counting circuit, remains reset, and S1i keeps A4 in the RESET state. Thus only the 'RESET' and '0' inputs to A5 are HIGH; A5 pins 6 and 9 remain LOW, and A5 pin 10 and A7 pin 2 remain HIGH.

Further, S3, the '+, OFF, -' switch, which in the AUTO mode could give only HIGH signals at A6 pins 2 and 5 and thus could have no effect, can now take these inputs LOW because of the LOW signal applied to its poles via S1g. S1g also keeps A8 pins 4 and 10 in the HIGH state.

Similarly, S2, the X/Y coil selector switch, which in the AUTO mode could have no effect because of the LOW signal at A8 pin 2, is now able to produce either a HIGH or a LOW signal at A8 pin 3 because of the HIGH signal applied to A8 pin 2 by S1f.

The net effects of switching to MANUAL SCALE-VALUE or ORIENT are as follows (refer to Figure 4.2):

* S2, drawn in the X position, allows the signal at A8 pin 1 to be LOW, giving a HIGH signal at A6 pin 8. A6 pin 9 is maintained HIGH by the signal at A8 pin 4. Thus, A6 pin 10 is LOW and relay K3 selects the X coils. Switching S2 to the Y position takes A8 pin 1 HIGH and produces a HIGH level at A6 pin 10, so activating relay K3 and selecting the Y coils.

* S3 is a three-position toggle switch. As drawn in the schematic, i.e. in the '+' position, it sets the + SOURCE ENABLE line HIGH and the - SOURCE ENABLE line LOW, thus selecting the positive output current source. When S3 is set to its central or 'OFF' position, only the pole associated with the + SOURCE ENABLE line changes over, the other pole remaining as per the schematic; thus both + and - SOURCE ENABLE lines are LOW and there is no input to the voltage-to-current converter, and so no output current (apart from that due to offsets --- see Section 2.2). In the '-' position of S3, both poles are changed over so that A6 pins 1, 2, 5 and 6 are all HIGH. This produces a LOW signal on the + SOURCE ENABLE line and a HIGH signal on the - SOURCE ENABLE line, and so selects the negative output current source.

* The LOW level switched to A8 pin 8 by S1g causes the

CURRENT ON relay, K2, to remain on and the integrator to remain enabled (via A8 pin 11 as before).

* 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 power is on.

4.11 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.

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[signature]	2/2/83		VARIOUS	2

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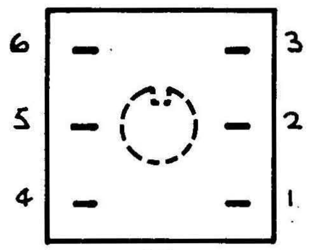
P. O. Box 378, Canberra City, A.C.T. 2601

S1 —— SEE SHEET 2a & PARTS LIST
S2 —— C & K 7101 S.P.D.T.
S3 —— " 7211 D.P.D.T. (SPECIAL)
S4 —— " 8221 D.P.D.T. (PUSH BUTTON)

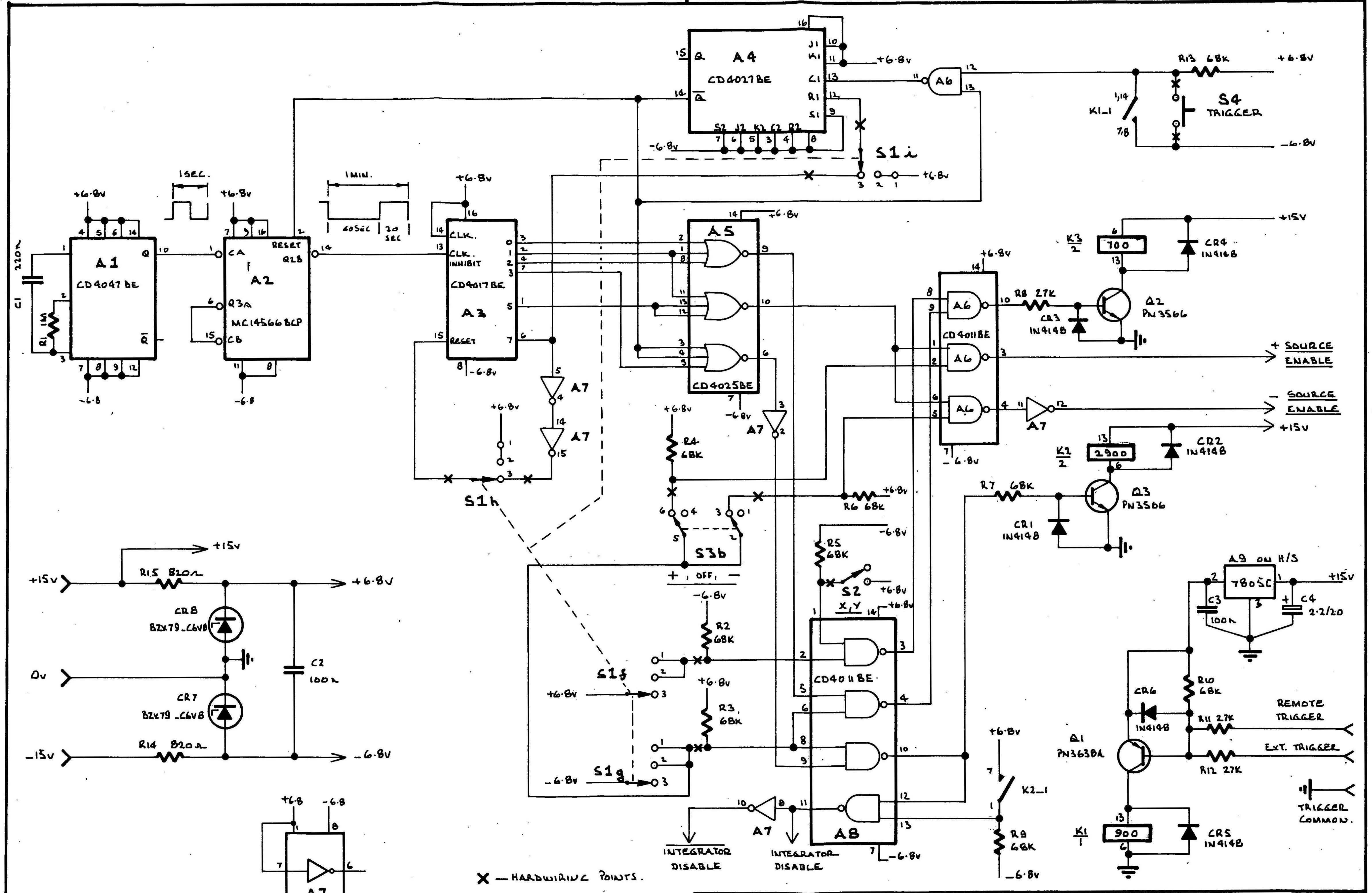
K1 —— ERNIE DILRID _ B _ 1A4.5 _ 5V
K2 —— " DILRID _ B _ 2A4.4 _ 15V
K3 —— " DILRID _ B _ 2W4.3 _ 15V
} IN SOCKETS.

7211



S3

VIEW FROM BACK



Drawing No.	Sheet No.	Title: MCC.1 MAGNETOMETER CONTROLLER SCHEMATIC No 1
M8	2	

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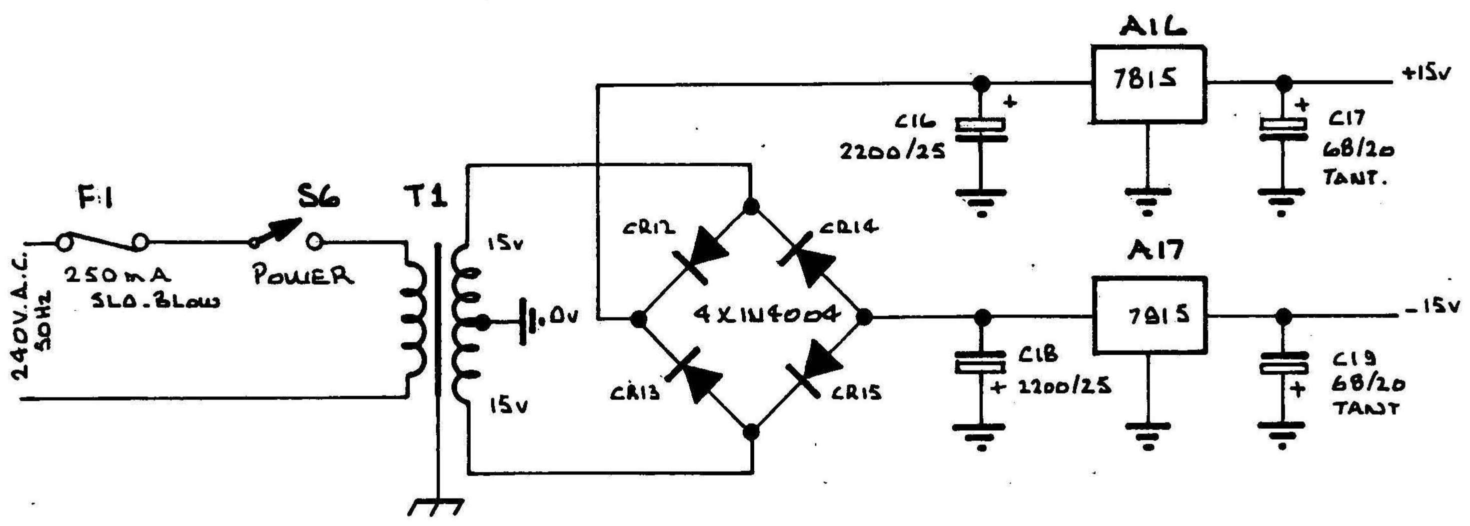
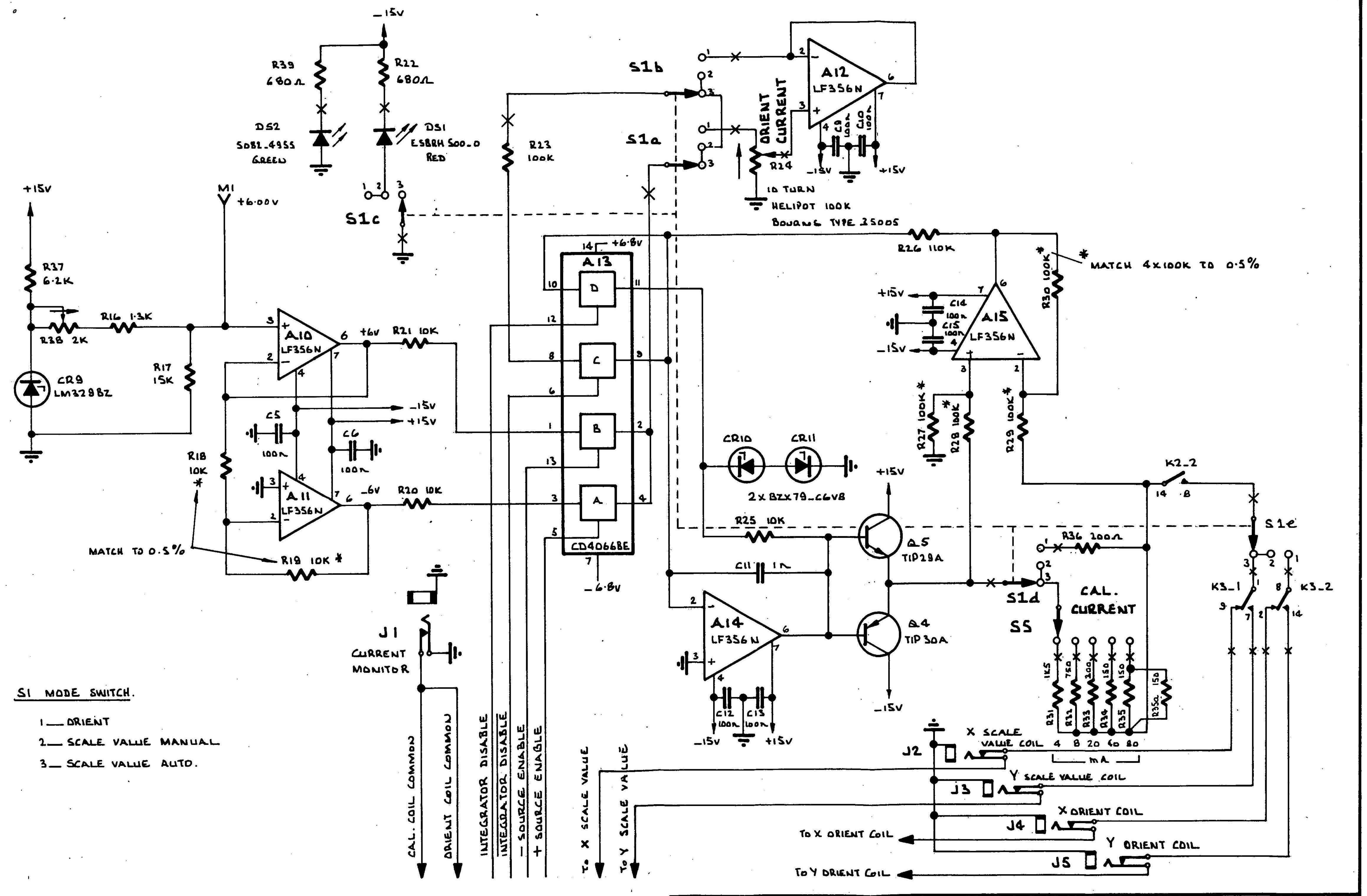
[illegible]	19/12/82		VARIOUS	2
[illegible]	3/2/83		″	3





Drawing No.	Sheet No.	Title:
MB	2a	MCC-1 MAGNETOMETER CONTROLLER. SCHEMATIC No2 / P.S.

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[illegible]	18/1/83			1

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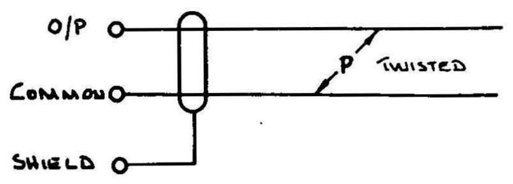
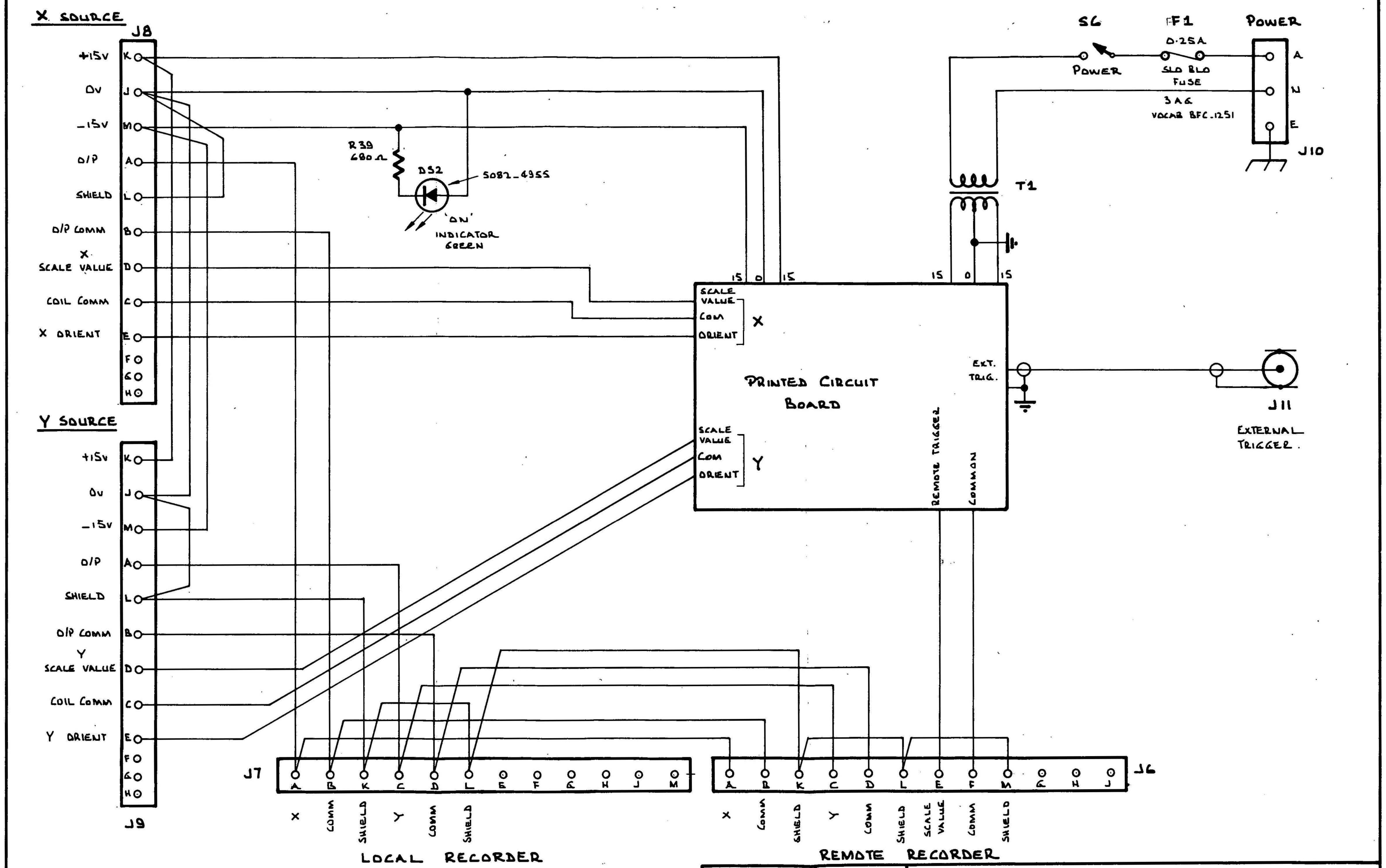
P. O. Box 378, Canberra City, A.C.T. 2601

CABLING: FOR CABLES BETWEEN THE MPE-1 SOURCE UNITS AND THE MCC-1, AND ALSO BETWEEN THE MCC-1 AND RECORDERS, THE ANALOGUE OUTPUT SIGNALS TO THE RECORDERS SHOULD BE RUN IN TWISTED SHIELDED PAIR.



TERMINATE THE SHIELDS AT THE MCC-1 END ONLY. SIMILARLY FOR THE REMOTE TRIGGER CABLE.



Drawing No.	Sheet No.	Title:
M8	3	MCC-1 CHASSIS WIRING, POWER SUPPLY, ETC SCHEMATIC.

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, 5, 6, 8, 13	"	"	BHS-40	5
	16-PIN	"		FOR A2-4, 7.	"	"	BHS-44	4
CR1-6				SILICON DIODE	PHILIPS	IN4148	BVD-IN4148	6
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
CR12-15	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
Module: CONTROLLER MCC1

COMPONENTS COMPOSITE
SHEET No. M8/2(i) ISSUE 2
DRAWN KAM DATE 1/2/83

1980 A

Item	Value	Vw	Tol %	Type	Make	Maker's Ref	BMR Vocab	Qty
Q1				TRANSISTOR, PNP	FAIRCHILD	PN3638A	BVT-PN3638A	1
Q2,3.				TRANSISTOR, NPN	"	PN3566	BVT-PN3566	2
Q4				TRANSISTOR, PNP	"	TIP 30A	BVT-TIP30A	1
Q5				TRANSISTOR NPN	"	TIP29A	BVT-TIP29A	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.	68µF	20	10	CAPACITOR, TANTALUM	SPRAGUE	CS13BE-686K	N.I.V.	2
C7,8,11.	—			NOT IN CIRCUIT				
R1	1MΩ	0.5	2	RESISTOR, TIN OXIDE	WELWYN	MRS	BRB-56105	1
R2-7,9, R10,13.	68k	0.4	2	RESISTOR, METAL FILM, MR25.	PHILIPS	2322-151 46803	BRA-55683	9
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-2-106	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, " " "	"	... 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-J5				PHONE JACK, TIP & SLEEVE WITH NORMALLING CONTACT	EQUIV. TO BULGIN	J12	N.I.V	1
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	3
S1				SWITCH, 3 SECTION, 3 POLE, 3 POSITION. BREAK BEFORE MAKE.	N.S.F	TYPE A	BSW-33	1
S2				SWITCH, SPDT, PUSH BUTTON	C & K	7101	BST-22	1
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

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		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-J9	12-PIN			CONNECTOR, BOX MTG	CANNON	KPTO-2E 14-12S	BKF-019	4
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

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		SHEET No. M8/2(iv) ISSUE 1
	Module: CONTROLLER MCC1	DRAWN KAM DATE 2/2/83

1980 A