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Record 1979/11

Macquarie Island Geophysical Observatory
Annual Report 1975

by

J. Silic

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CONTENTS

		Page
	SUMMARY	
1.	INTRODUCTION	1
2.	GEOMAGNETISM	1
	Magnetometers	1
	Normal-run magnetograph	3
	Rapid-run magnetograph	4
	Scale values	5
	Orientation tests	6
	Data	6
3.	SEISMOLOGY	7
	Telemetry seismograph	8
	Wireless Hill site testing	9
	Possible improvements to seismological recording	12
4.	POWER AND TIMING SUPPLIES	12
	Central power and timing arrangements	13
	IC-723 Power Supply	13
	Synchronised Inverter	14
	Earth points	15
	Seismograph power system	15
	Seismograph lamp power supply	16
	Seismograph timing system	16
	Time mark monitor	17
5.	OTHER DUTIES	18
	Tide gauge	18
	Station duties	18
6.	ACKNOWLEDGEMENTS	18
7.	REFERENCES	18
	APPENDIX 1	20
	Operation of Power and Timing Control Board (PPT-1A)	20
	APPENDIX 2	24
	Operation of Synchronised Inverter	24

Page

TABLES

1. Magnetogram parameters 27
2. Normal-run magnetogram baseline values 28
3. Preliminary monthly mean values 29
4. Orientations of variometer magnets 29
5. Geomagnetic annual mean values 1963-1975 30
6. Electrical earth connections 31
7. Felt earthquakes 1975 31

PLATES

1. Central power and timing arrangements
2. Power and timing control PPT-1A
3. Power Supply IC-723
4. Seismograph power system
5. Seismograph lamp supply
6. Seismograph timing system
7. Seismograph time-mark monitor
8. Seismograph timing relay circuits
9. Seismometer control panel
10. Inverter - Oscillator and synchronising circuit
11. 1975 Seismometer sites.

SUMMARY

Geomagnetic and seismological recordings were continued throughout 1975 at Macquarie Island. A 20 mm/h magnetograph recorder was installed in place of the original La Cour 15 mm/h recorder.

The entire seismograph was re-installed in the seismograph vault and a new power and timing arrangement for it was designed and built; it features a circuit that switches in the standby chronometer if the primary time source fails.

Central power and timing arrangements were improved; a synchronised inverter was added to provide frequency-regulated power for the recorders and a DC power supply was built to provide power for the magnetograph lamps and the control panel.

The telemetric seismograph was made operational; a new type of seismic pit was tried in order to provide better access for testing the telemetry equipment, and five sites on Wireless Hill were tested as possible replacements for the original seismograph vault, but none of them was significantly better.

1. INTRODUCTION

This Record describes the operation of the Macquarie Island Geophysical Observatory while the author was the Observer-in-Charge; he succeeded Mr J. Walsh on 25 November 1974, and was relieved by Mr P.R. Gidley on 25 November 1975.

The Bureau of Mineral Resources, Geology & Geophysics (BMR) has carried out seismological and geomagnetic recordings at Macquarie Island since 1950 and 1951 respectively, as a part of the operations of the Australian National Antarctic Research Expeditions (ANARE); the Antarctic Division of the Department of Science has provided accommodation and logistic support for this work.

The operation of the observatory in earlier years is described in annual BMR Records (e.g. Meath, 1971; McDowell, 1973; McMullan, 1974; Hill, 1974; Walsh, in prep.).

2. GEOMAGNETISM

Magnetometers

The absolute and semi-absolute instruments listed below were used up to eight times a month to determine baseline values for the normal magnetograms:

Component		Instrument	Preliminary correction
Declination	D	Ask. 640505 Circle 640620	0.0'
Horizontal intensity	H	QHM 177	-10 nT
		QHM 178	- 3 nT
		QHM 172	-28 nT
Vertical intensity	Z	BMZ 236	-49 nT
Total intensity	F	Elsec PPM 421	0 nT

The PPM values of F were combined with magnetogram values of H (adjusted by the preliminary corrections in the table) to derive 'proton' baseline values Zp for comparison with BMZ values. These yielded the BMZ correction in the table. For a number of years the BMZ correction had been about -147 nT, but analysis of 1974 results showed that it changed abruptly to about -49 nT in October that year.

Subsequent analysis of the year's baseline values gave these differences between the QHMs:

QHM.177 - QHM.178 = 7.0 ± 2 nT

QHM.177 - QHM.172 = -18.6 ± 3 nT

which are in good agreement with the differences indicated by the preliminary corrections.

The magnetometers were standardised by intercomparison with magnetometers from Toolangi Magnetic Observatory, the results being:

<u>March 1975</u>

D: Ask.812 - Ask.505 = 2.1' ± 0.1'

F: PPM.340 - PPM.421 = 0 nT

<u>November 1975</u>

D: Ask.812 - Ask.505 = 2.2' ± 0.2'

H: QHM.177 - HTM.704 = 12.0 ± 1.0 nT

QHM.177 - QHM.179 = 7.7 ± 1.5 nT

F: PPM.271 - PPM.421 = 0 nT

The suspension in QHM.179 had been broken in 1974, and a new one fitted at Rude Skov Observatory during 1975; the QHM was retained at Macquarie Island after November 1975, when its correction was about zero.

<u>Pier corrections.</u> From April 1974 to 28 June 1975 the BMZ was left in the absolute hut during absolute observations. This made a difference of +24 nT to the value of F at Pier W, and -0.7' to D at Pier E; H on Pier E was not affected. Hence, values obtained between those dates should be corrected accordingly. When the BMZ is not in the hut the F differences between Piers E and W was less than 1 nT.

Interference on PPM. In August the PPM was made useless by the sudden appearance of an interfering signal in the absolute hut. The nature of the interference was very similar to that produced by the AC mains, viz. the signal-meter did not show the proton-signal decay, but showed a steady, strong signal.

After two weeks of searching the source of interference was traced to the manual time-mark switch wiring which is fixed to the sides of the absolute piers, and to the Power and Timing Board (PPT-1A) in the geophysical office.

The PPM would work only if the sensor was not on or very near the two absolute piers, or if the secondary power (mains) was disconnected from the PPT-1 board. The problem was solved by properly earthing the negative rail of the DC supply for the magnetograph time-mark circuit.

In the past this supply had also served as an external 12 V source for the radio, and through the radio circuit arrangement its positive rail was earth. When the connections to the radio deteriorated the supply lost its earth and subsequently the PPM was made useless.

To make the earth for this supply clearly visible, a wire from the earth stake was connected to a set of terminals on the wall of the geophysical office, and the negative rail of the supply was connected to one of the terminals. At the same time the supply was disconnected from the radio and two 6 V dry cells were used for radio power.

Magnetographs

Two sets of continuous recording magnetographs were in operation during 1975:

(1) La Cour normal-run three-component magnetograph (15 mm/h to 28 April, 20 mm/h from 28 April).

(2) La Cour rapid-run three-component magnetograph (180 mm/h).

Normal-run magnetograph (N/R)

All numerical data were derived from this instrument; a summary of the baseline values is given in Table 2.

The magnetograph which from 1951 had recorded at 15 mm/h was changed to record at 20 mm/h on 28 April. This change was made in accordance with IAGA

Resolution No. 19 (IAGA, 1973), and included the installation of a new recorder and the re-aligning of all prisms and lenses. The recorder was designed and made in the BMR Workshops and utilised existing components as far as practicable. The quality of traces improved markedly during the conversion; correct intensity of the H baseline was achieved partly by masking a small portion of the H lens.

Before the recorders were changed the lenses and the slit had to be adjusted about once every six weeks. The deterioration in the traces was due mainly to changes in the position of the slit, usually by it being knocked by the cover during record changes (the slit was not positioned at its lowest point so it could be readily jarred out of position). When the new recorder was installed the slit was set at its lowest point and the lenses and prisms were adjusted accordingly to prevent this deterioration.

Thermograph. Two temperature traces can be obtained from the normal variometers: one from the H variometer with a scale value of about 6°C/mm and the other from the Z variometer with a scale value of about 1.4°C/mm. The latter is used for all variometer reductions, because of its higher sensitivity and because temperatures within the variometer room are sufficiently uniform. Because the H temperature trace is not used it is not made to record on the new 20 mm/h records; this simplified the production of good H traces.

The thermograph scale value and baseline value (Tables 1, 2) were calculated by least-squares analysis of the data obtained from the daily temperature readings and corresponding temperature trace ordinates.

Temperature coefficients. The temperature coefficients (q) of the H and Z ordinates were determined by least-squares analysis of the observed baseline values and the corresponding temperatures derived from the thermograph data. The adopted values were the same as those used in earlier years, viz.

$$qH = 3.0\ nT/^{\circ}C$$
$$qZ = 0.0\ nT/^{\circ}C$$

Rapid-run magnetograph (R/R)

The magnetograph gave no problems mechanically, but the quality of the traces was improved.

Two new long mirrors (H and D) were installed, and the H long mirror was shifted a significant distance from its old position so that all possible reserve traces could be recorded.

During severe magnetic storms, the bottom parts of large H bays could not be recorded. This is because the sensitivity of the H variometer is too high for the number of reserve prisms provided.

Scale values

BMR magnetograph calibrator MCO-1 was used as a current source for determining the scale values of all six variometers. The results are summarised in Table 1.

The outputs of the calibrator were monitored throughout the year, the voltage output to 0.2% by using a digital voltmeter, and the current output to 0.3% by using a first-grade moving-coil ammeter. During the 1975 changeover a better digital multimeter was received and the outputs were checked. It was confirmed (as indicated during the year and allowed for) that all current outputs were 0.2% higher than the nominal values shown on the range-selector of the calibrator (i.e. V_{out} of the calibrator was 5.01 instead of 5.00 V).

The magnetograph calibrator had the following problems:

(1) The output varied with the setting of the rise-time potentiometer.

(2) The current rise and fall times, which should be equal at a given setting, were different; the rise-time did not increase proportionally to the increase in the setting of the rise-time potentiometer, and the current did not decay if the potentiometer was set to a nominal rise-time of more than 50 seconds.

(3) The current output was different for the two positions of the current reversing switch.

All these problems were eliminated by joining capacitor C4 to resistor R9 by a piece of wire four times longer than the one that was in the circuit. No satisfactory explanation can be given for this solution; it was arrived at after many hours of work, and by sheer chance.

(These problems were also found in Mundaring's calibrator, when the author was at the observatory after his return from Macquarie Island. Again, the calibrator was fixed by joining C4 to R9 by a longer piece of wire).

Orientation tests

Orientation tests were done on all variometers. Results are in Table 4.

By checking the wiring and by passing currents of the same sense through the D scale-value and H orientation coils (which are parallel to each other), and through the H scale-value and D orientation coils (which are also mutually parallel), it was confirmed that the currents produced fields of the opposite sense to that indicated by the MCO-1 unit (which supplies the R/R orientation current), and also to that shown by the MCO-3 (which provides the larger current for the N/R coils). To correct this, the MCO-1 unit was relabelled, and the internal battery in the MCO-3 was taken out of circuit. To do N/R orientation tests subsequently, an external battery together with a 1000 ohm potentiometer and an ammeter had to be plugged into the jack point of MCO-3. With this jack-plug, correct field directions were produced in D and H orientation coils when the positive side of the battery is connected to the red lead of the jack-plug.

To check that correct field directions are being produced, proceed as follows:

(1) For D orientation, make a manual H scale-value test. The wiring is such that the direction of the field produced by the H scale-value coil with coil switch on H1+ is the same as that produced by the D orientation coil with coil switch on D1+.

(2) Similarly, to check the H orientation field, make a manual D scale-value test (the field is northerly, the same as produced when the D coil switch is on D1+).

Data

Preliminary data were derived and cabled monthly to the BMR office in Melbourne for distribution; they comprised the monthly mean values of D, H, and Z, and the K-indices of geomagnetic disturbance, all derived from the normal magnetograph.

The monthly mean values are shown in Table 3, and the annual mean values for all elements are included in Table 5, which demonstrates the secular variation over the last thirteen years.

Subsequently (after returning to Australia), information on selected geomagnetic storms was compiled for World Data Centre A, for publication in IAGA Bulletin No. 32 f.

Mean hourly values of the trace ordinates were measured and tabulated at Macquarie Island during the year; they will be used by the Canberra Group to derive magnetic mean values for publication and lodgement with the World Data Centre.

3. SEISMOLOGY

In October 1972 a new seismograph (MQI) had been brought into operation, (McMullan, 1974); its sensing station was situated on Boot Hill at an elevation of 250 m on the main plateau, 3 km from the ANARE base, and the object was to improve on and replace the vault seismograph (MCQ), which is situated on the slopes of Wireless Hill near the ANARE base. However, MQI had operated with difficulty owing to numerous landline failures (Hill, 1974) till the beginning of 1974 (Walsh, in prep.), when it was taken out of operation and the old MCQ site was re-occupied.

On taking over the station in December 1974 the seismograph situation was:

(1) The working seismograph was an electro-mechanical system located in the seismograph vault. This comprised a Willmore Mk 1 seismometer (To = 0.9), a short-period (0.2 s) galvanometer, and a BMR 30 mm/min recording drum. The power for the drum came from a 20 W Transtronic frequency-stabilised 240 V source. The time marks came from the clock in the geophysical office.

(2) The FM telemetry seismograph, which was not operational owing to the faulty land-line to the seismometer site on Boot Hill and to faults in the telemetry equipment. The system is fully described by McMullan (1974) and Hill (1974).

(3) A recording room in the geophysical office contained a 60 mm/min recorder for the FM seismometer; it ran off a 30 W Transtronics frequency-stabilised 240 V source.

The vault seismograph was immediately upgraded by replacing the BMR recorder with the faster 60 mm/min one. When the cable from the geophysical office to the vault was overhauled and three pairs of wires became available, the 50 Hz regulated power (synchronised inverter or EMI) was connected to the vault to run the recorder motors. The control panel for the seismograph is shown in Plate 9. Other improvements to the timing and power supplies are described in Chapter 4.

The vault seismograph (MCQ) operated satisfactorily throughout the year as the regular observatory instrument. It was also used as a reference in the evaluation of relative ground-noise levels at other sites. Data from the seismograph were sent by telegram to BMR's office in Melbourne for distribution to Australian and overseas organisations. After return to Australia the seismograms were re-analysed and the final data lodged with the International Seismological Centre (Edinburgh). Information on two felt earthquakes is given in Table 7.

The telemetry seismograph was restored to working order and used to test several sites on Wireless Hill with the object of finding a better site than the vault but which does not have the disadvantages encountered on the main plateau. Details of this work, the results of the tests, and some recommendations for future consideration, are given in the next section.

Telemetry seismograph

In December 1974 one amplifier-modulator worked and one discriminator worked partly. Repairs were carried out on the faulty discriminators and the amplifier-modulator but owing to lack of proper spares non-standard transistors and operational amplifiers were put in. This involved some minor changes in the circuitry, but once the units were fixed no serious problems were encountered.

A new seismometer control panel (Plate 9) was built. The resistors were chosen so that the seismometer damping ratio was 17:1. The resistor values were calculated from the data in the Willmore Mark II seismometer handbook.

The seismometer control panel is located in the box containing the amplifier-modulator, and it performs three functions:

(1) It provides the proper damping resistance for the seismometer when the switch is on RECORD, which is the normal operating position.

(2) It enables the measurement of the seismometer free-period by turning the switch to FP and then making the mass oscillate, either by sharply pulling a magnet away from the seismometer or by pushing the calibration magnet.

(3) It enables the seismometer to be isolated from the amplifier when the switch is in the OFF position.

Because of the high level of ground noise at Macquarie Island, it was decided to attenuate the seismometer signal before it reaches the amplifier. This was done by arranging the damping network so that there were two resistors (4.7 K) in series with the coil and amplifier, and two (3.9 K) in parallel. By attenuating the seismometer signal, a better noise-to-saturation signal (signal that saturates amplifier) ratio is obtained. The present attenuator attenuates the signal by a factor of 3.35. There is no reason why this cannot be larger.

To keep check of the landline, resistances are given as measured in the vault with the sending station connected and the discriminators and power supplies disconnected. All resistances were measured with an AVO-8 meter;

Shield (AVO common on shield)	- Black (+12V) 12K
	- Red (calibrator) open
	- Blue (modulated signal) open
	- Yellow (-12V) 2.2K
	- White (calibrator) open
	- Green (modulated signal) open
Yellow (AVO common on yellow)	- Black (-12V, +12V) 20K
Green	- Blue (modulated signal) 700
White	- Red (calibrator) 220

Any marked departure from these values indicates a cable fault.

The calibrator magnet was broken, so complete calibrations could not be made, but weight-lift tests showed that the telemetry seismograph magnification was about the same as when it was at the plateau station in 1973 (1973: 41.4 mg weight gave a 7.1 mm deflection; 1975: 50 mg gave 11.8 mm at its best magnification; 9.4 mm at the average magnification).

Wireless Hill site testing

The telemetry receiving/recording equipment was transferred from the Geophysics Office to the seismograph vault, and a landline was run from there to the sensing/transmitting equipment at the test pit. This was advantageous because:

(a) Not as much cable had to be laid to reach a sensing station.

(b) The distance of the seismic vault from the main radio transmitting aerials precluded the pick-up of RF interference as previously encountered at the Geophysics Office.

In testing sites on Wireless Hill two innovations were tried as possible improvements on the previous telemetry system:

(a) All cable joints were completely potted in epoxy resin (in contrast to the original setup (McMullan, 1974) in which cable connectors were housed in wooden boxes and the joints were sleeved, soldered and covered with silicon grease to exclude moisture).

(b) Units of the sensing station were housed separately.

Previously the amplifier/modulator and the seismometer were in the same pit, which left very little space for testing the equipment. In the new arrangement the seismometer was placed in a concrete pit about 1-1½ m deep, while the amplifier/modulator, the seismometer control panel, and the cable connections were in a large wooden, steel-lined, well-waterproofed box, partly buried about a metre away from the seismometer pit.

Six test pits were dug on Wireless Hill (Plate 11). All but one (75/6) were fully tested - pit 75/6 was abandoned before testing, because of bad drainage in the area. The choice of test sites was limited because most of Wireless Hill is either heavily overgrown by tussocks or covered by badly drained soil. All of the pits were dug in soil and weathered rock fragments; in areas of exposed rock they were dug to a depth of 1-1½ m; long steel spikes were driven into the ground at the base of the pit, and then a base of concrete 30 cm thick was poured. Attempts to reach bedrock on site 75/2 were unsuccessful; the best that was achieved was the reaching of large rock fragments or boulders. In the areas with exposed rock most of the rock was well weathered and easily broken. All the pits had to be dug using shovels and crowbars because no dynamite was available, which made it impracticable to reach bedrock because of the difficulty in digging deeper than 1½ metres. The concrete for all the pits was mixed on Wireless Hill, because water is readily available there in ponds. This made the job somewhat easier and allowed the author to complete the task on his own if he desired. The screenings, sand and cement were carried in packs to the top of Wireless Hill and mixed on a fibro board.

The concreting of one pit usually took 3-5 days; the man-handling of the materials to the top of Wireless Hill took more than a day.

At each pit recordings were made for about 4 or 5 weeks; comparison with the simultaneous vault recordings showed which of the two seismographs recorded more earthquakes, and the effect of different weather conditions at each station. Direct comparisons were obtained twice between two test stations (75/1, 75/4) and the seismograph vault. This was done by recording with the telemetry equipment at the vault for a few hours, and on the same day (same record) shifting the telemetry sending equipment to the test pit. The author thinks that this was the most effective way of comparing noise levels at two stations because the vault and telemetry seismographs have markedly different responses at the periods of the ground-noise; the telemetry seismograph is about twice as sensitive, making it very difficult to obtain accurate values for the relative noise levels at the test pit and vault.

Results. None of the pits was good enough to warrant abandonment of the vault. It should be noted that the seismometer foundations at the vault were superior to those at the test pits; none of the test pits was on bedrock, and the walls of the pits started crumbling after about two weeks, because of moisture getting into the walls. It was impracticable to place the fibreglass cover in the pit and concrete it in because the pits were temporary and the fibreglass box (which protected the seismometer) had to be taken out after testing each pit.

In contrast to previous years, no problems were encountered with the cable. The author believes that this is mostly due to every joint in the cable being potted completely and supports Hill's (1974) findings; he made most of the joints in the old cable permanent, and found that only once was a potted joint at fault. (This was due to not making the joint properly in the first place because of the difficult conditions under which he was working). After seven months the cable on Wireless Hill was still in perfect working order. The last tests done in November indicated no reduction in the open circuit interlead resistances (all were infinity) and there was no evidence of deterioration of the PVC covering. However, it should be noted that the cable on Wireless Hill was laid along the ground, and therefore was not subject to the same stresses as the previously suspended cable. It was possible to lay the cable on the ground because there are few rabbits on Wireless Hill.

Possible improvements to seismological recording

In order to obtain a higher magnification from a seismograph the signal-to-noise ratio has to be increased, either through finding a quieter site or by filtering the noise electrically or mechanically. Mechanically the noise may be filtered by altering the seismometer free period. Experience has shown that the signal from the discriminator has to be attenuated by 4 dB if the seismometer period is increased from 0.7 s to 1.0 s, so a reduction of the free period to 0.7 s may improve the recording of local earthquakes. Simple electrical filtering could be achieved by connecting an RC network across the output of the discriminator, and using the voltage across the resistor as the input to the galvanometer. The values of the filter components could be varied to achieve the required pass band, depending on the noise spectrum.

If it is ever decided to resume the search for a site on the plateau it may be possible to lay the cable on the ground for part of the way because very few rabbits were seen along the track from Boot Hill to the Ski Hut. Rabbits were mainly seen on the coastal side of North Mountain, North Scree and in the area of Gadgets Gully, Perserverance Bluff and Razorback Hill. To substantiate this observation, old cable that was left lying on the ground from Boot Hill to the Ski Hut showed no evidence of serious damage to the PVC covering.

4. POWER AND TIMING SUPPLIES

A standardised power and timing scheme for Antarctic observatories was introduced in 1970 (see Meath, 1971). The main feature of this was the placement of primary and secondary sources of power and time-marks, and associated control boards, in a central location (the Geophysics office); thus both the seismograph and the magnetograph were controlled from a common source (except in emergencies, when individual sources were used).

Since 1970 minor changes have been made to the scheme and in 1975, when it was decided to re-occupy the original seismograph vault, further additions and modifications were made. Therefore it is necessary to describe the revised arrangement in detail; in particular, it should be noted that the main 'Power and Timing Control Panel' is no longer 'standard' and it is essential that the revised instructions given in Appendix 1 are used to operate it. The modified panel has been re-labelled type PPT-1A.

Central power and timing arrangements

The central power and timing unit situated in the geophysical office allows for the following:

(a) The use of an EMI crystal clock or Mercer chronometer for time control, either to drive the Time Mark Programmer Unit (TMU-2); or to send time marks directly to the seismograph and magnetograph in case of TMU-2 failure.

(b) The use of a TMU-2 programmer which sends time-mark suites to the magnetograph and seismograph. By means of the 'Power and Timing Control' Board PPT-1A, the seismic marks can be in the form of closures or voltage steps.

(c) The choice of frequency-regulated or unregulated power for drum motors.

(d) The use of the EMI crystal clock to synchronise an inverter for the provision of frequency-regulated power for drum motors.

(e) The use of a DC power supply (IC-723) with good load/line regulating characteristics to run the magnetograph lamps and magnetograph control board MCO-3.

(f) The use of a time-signal receiver to send 1 s pips to the seismograph timing system and the EMI clock.

The block diagram of the system is in Plate 1, and Plate 2 is the circuit diagram of the control panel PPT-1A; Appendix 1 gives details of the operation of the panel.

The unit uses two 24V lead/acid batteries. The first battery with a boost charger on it provides 24V power for the inverter, while the second battery provides power for the EMI clock and IC-723 power supply during mains failure. The second battery does not need to be on continuous charge, because it only comes into use during power failures. If this battery is checked at regular intervals and charged when needed, no problem should be encountered during mains power failures. The two batteries are isolated because:

(1) Only the inverter battery needs to be charged continuously.

(2) After a prolonged power failure the total load for a single charger would be heavy, viz.: Inverter 5 A, EMI 3A, IC-723 1½ - 2 A.

IC-723 power supply. Originally the power supply was a 12V battery on float charge, providing 12V for the TMU-2 and PPT-1 Board, and through a regulating circuit, 9 V for the magnetograph lamps.

The supply was replaced for the following reasons:

(1) The 9 V regulator had poor load/line regulation. This meant that during power failures the output of the regulator would drop causing an appreciable decrease in magnetograph trace intensities; and if a lamp burned out (resulting in decrease in load) the regulator output would increase resulting in thickening of the remaining traces.

(2) The new, faster 20 mm/h recorder uses less sensitive FP4-C photographic paper and needed a power supply for its lamps with a minimum output of about 10 V.

(3) The TMU-2, as noted in the past, does not function properly if the input voltage drops below 12 V. When using the 12 V battery the supply problems were frequent during power failures. A power supply with an output of more than 12 V during power failures was needed to eliminate this problem.

The new supply (IC-723) has good load/line regulating characteristics and provides an output between 10.8 and 14.3 V at 3½ - 4 A. It is normally operated at 13 V, and runs the magnetograph lamps, MCO-3 board, TMU-2, PPT-1 and the NTO-1 relay.

The regulator of the supply (Plate 3) is a 723 DC voltage regulating chip and the output stage consists of transistors Q1 and Q2. The output is varied through the 1K potentiometer.

Standby power for the supply is an 18 V tap on the 24 V battery bank that supplies the EMI clock. During power failures diode CR1 becomes forward-biased and the 18 V battery output is then regulated. When the mains power is on, CR1 is reverse-biased and the battery is trickle charged through the 10 ohm resistor. The output of the bridge rectifier is then being regulated.

Synchronised inverter. A 24-240 V 250 VA inverter was added to the system to supply primary or secondary power to the recorders. It was placed in the cold porch (Geophysics office) because of the noise it makes when operating.

The inverter operates in two modes:

(1) The synchronised mode which gives 240 V at 50 Hz; frequency-regulated. The synchronising source is a 3-4 V 50 Hz square wave from the EMI crystal clock.

(2) The asynchronous mode which gives 240 V at variable frequency. In this mode the inverter produces its own frequency which can be adjusted.

Several problems had to be overcome before the inverter became fully operational.

The major problem was the very small range of its own frequency over which the inverter would synchronise with the clock. As the inverter frequency drifted outside this range, the inverter would revert to the asynchronous mode; this occurred about once a month.

The problem was solved by:

(a) Putting diodes MR18, MR19 (Plate 10) the right way in (the manufacturers had put them in back to front).

(b) Increasing resistor R21 from 39K ohms to 56K ohms; decreasing R14 from 2.7K ohms to 1.5K ohms and increasing R13 from 5.8K ohms to 8.2K ohms.

The above action increased the size of the synchronising spikes arriving at base b2 of the unijunction transistor VT3, and consequently increased the synchronising range.

The other main problem was spurious triggering of the inverter. This was due to the appearance of spikes on the synchronising wave form. The problem was eliminated by providing a better earth for the synchronising wave.

A detailed description of the inverter and the procedure for synchronising it are given in Appendix 2.

Earth points. Numerous problems were encountered in the Central Power and Timing arrangement owing to lack of or inadequate earth points, and to a power point which was switching through neutral.

An earth-lead from the earth-stake was connected to a set of terminals on the wall in the geophysical office, and most of the points that needed to be earthed were connected to one of these terminals.

Table 6 lists the earth-points and the need for each of them.

Seismograph power system

After the shift to the seismograph vault a new power system was designed and built. The arrangement is shown in Plate 4.

The primary power for the recorder motors comes from the geophysical office via a cable. In the event of primary power failing, a relay connects a 20 W Transtronics frequency-stabilised source to the recorder motors.

All the DC supplies for the telemetry equipment run off raw 240 V mains, the back-up being an AWA 12 V - 240 V 40 W DC inverter. This inverter has an in-built mains-failure relay for automatic changeover.

The 12 V battery that is continuously charged at about 1½ A provides 12 V for the timing system and, through a regulating circuit, power for the seismograph lamps at 6-9 V.

Seismograph lamp power supply. The power for the lamps in the past was a 12 V battery on continuous charge. This arrangement worked well except during power failures, when the voltage to the lamp would eventually decrease and there would be subsequent thinning of the trace. For this reason it was decided to build a regulating circuit with good load/line regulating characteristics.

The power supply (Plate 5) consists of:

(1) Constant current source (CR1, Q1, R1, and R2) to the reference Zener CR2.

(2) Difference-amplifier (Q2, Q3), which keeps point B in the 5K ohm potentiometer at the reference Zener (CR2) voltage.

(3) Constant current source (Q4, R4, R5, and CR3) to Q3, Q5, and Q6.

(4) Output stage Q5 and Q6.

(5) The 5K ohm potentiometer that sets the voltage.

The output voltage is given by:

$$V_{out} = V_{CR2} \times 5K/R_{BC}$$

and is kept constant through the difference-amplifier which keeps point B of the potentiometer at the reference Zener (CR2) voltage.

Should point B depart from CR2 voltage through the output of rectifier rising (or falling), the transistor Q3 turns on more (less), thus leaving less (more) current to the output transistors Q5 and Q6, and thus there is a correcting fall (rise) in the output, and the base of Q3 (point B) returns to the reference voltage.

Seismograph timing system

The seismograph timing (Plate 6, 7, 8) system has the following features:

(1) The system can accept either voltage or closure time marks from the control board PPT-1 in the office.

(2) The time-mark monitor monitors the arrival of time marks and if they stop arriving, connects in the standby timing system.

(3) The standby chronometer can be switched in manually for comparison with the primary time marks by referring to the seismogram, thus providing a direct measurement of the correction for the chronometer.

Time mark monitor. The function of the time-mark monitor (Plate 7) is to switch in the standby time mark if the primary time marks stop arriving from the geophysical office. It does this by measuring the time between successive primary time marks. If a time mark fails to arrive within a preset time (e.g. 65 seconds) after the last time mark was received, the NT01 relay of the standby chronometer is turned on. The same relay is also turned off automatically as soon as primary timing is re-established.

The monitor comprises:

(1) The timing circuit, consisting of C1, R1, R2, R3, Q1 and relay contact K1/1.

(2) The K2 relay switching circuit, consisting of Schmidt (Q2, Q3) trigger and transistor Q4. K2 relay closure acts as a switch to chronometer relay NT01.

(3) The provision for setting the time interval between expected successive time-marks. This is done by changing the setting of potentiometer R8.

The base voltage of Q3 is set by the potentiometer R8, while the base voltage of Q2 is the charge voltage of capacitor C1. If C1 is allowed to charge past the Q3 base voltage, Q2 will turn on, turning Q3 off, and correspondingly Q4 and relay K2 will turn on, and so the chronometer relay NT01 will start to provide time marks to recorder. If the Q3 base voltage is set properly, this does not happen with primary time marks arriving regularly. This is because during normal operations the capacitor C1 which charges through R2 and R3 (the two resistors also setting the upper limit to which the capacitor will charge) is being discharged once every 60 seconds through the turning on, of transistor Q1 by the arrival of a primary time mark; so by setting the base voltage of Q3 so that capacitor C1 cannot charge to it in 60 seconds, transistor Q3 cannot be turned off, as long as primary time marks are arriving regularly. In practice the Q3 base voltage is set so that C1 charges to it in about 62-65 seconds. In this case if a primary time mark fails to arrive, C1 keeps on charging, and in about 62-65 seconds from the last time mark that was received, it reaches the Q3 base voltage and K2 is turned on through Q3 turning off. This situation will remain until primary time-marks are re-established, and standby timing will be turned off at the arrival of the first primary time-mark.

5. OTHER DUTIES

Tide gauge

The tide gauge on Buckles Bay, belonging to the Horace Lamb Centre for Oceanographic Research, Flinders University, was kept in operation till June. The heavy easterly seas in June destroyed the siphon line and the fibro walls of the gauge housing were damaged. At the request of Flinders University the remaining workable parts were returned to the University at the end of the year.

Station duties

The author acted as a stand-in physicist for a few weeks. Assistance was given in general station duties. The absolute hut was painted internally, and the seismograph vault was painted internally and externally, rewired, and cleared of unwanted shelving and cabinets.

6. ACKNOWLEDGEMENTS

Thanks go to all the members of the 1975 expedition for their support and good company and for helping to lay the cable to Wireless Hill. Special thanks go to Ian Knight and Mick Hinchey, for looking after the observatory during the author's absence on field trips and for their extraordinary patience with the author on the numerous occasions that he asked to be supplied with electronic parts which he did not possess.

7. REFERENCES

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APPENDIX 1

Operation of Power and Timing Control Board (PPT-1A)

(Macquarie Island 1975 version)

The Block diagram (Plate 2) shows the main units of the system for providing power and time marks to the seismic and magnetic recorders.

We refer to the following:

Primary timing - EMI crystal clock
Secondary timing - Mercer chronometer
Primary power - Synchronised inverter - (The sync control is EMI clock) or the clock's 230 V output (if the clock can take the load).
Secondary power - The output of the un-synchronised inverter.
Mains power - The (variable frequency) station supply.

On the wall near the instrument console are three power points.

(1) Inverter power point
(2) EMI power point
(3) Voltage-regulated mains power point

There are also two power plugs leading into PPT-1A board by means of which connections to the above power points can be made. The first one leads to the inverter terminals of PPT-1A and is referred to as 'PPT-1A primary power plug', while the second one goes to PPT-1A mains terminals and is referred to as the 'PPT-1A mains plug'.

PPT-1A Panel Switch Functions

(1) Mode switch (S1) - The two positions of the switch refer to the origin of the time marks going to seismic and magnetic.

(a) TMU - The programmer TMU provides all time marks.

(b) Direct - Time marks are provided by EMI clock directly to seismic, and chronometer provides time marks directly to magnetic.

(2) Chronometer switch (S2)

(a) Compare - The chronometer time marks are connected directly to seismic time line for comparison with the EMI time mark, by reference to the seismogram.

(b) Standby - Normal operation position.

(3) Override switch (S3)

The two positions refer to the status of the EMI time mark when the primary power has failed.

(a) Off - The time marks from EMI are disconnected from TMU.

(b) On - The time marks from EMI are connected to TMU.

Note. If the chronometer is to provide time marks to magnetic directly, the override switch has to be off. To overcome this problem points D and E should be joined directly.

Operation of the Control Panel PPT-1A

(1) Normal operation (Primary power, primary timing, TMU provides all time marks)

Panel Switches

Mode - TMU

Chronometer - Standby

Override - Off

Relay K2 is activated by primary power so that:

(i) K2/1 breaks to disconnect chronometer time mark K1/1 from TMU input.

(ii) K2/2 changes over to connect inverter (Primary) power to recorders.

(iii) K2/3 makes to connect EMI time mark K3/2 to the TMU (Primary timing).

(2) Clock failure

(a) No TM output, sync pulse OK i.e. Primary power OK.

Disconnect the PPT-1A primary power plug from the inverter power point. At the power points on the wall, disconnect the PPT-1A mains from the mains power point and plug it into the inverter power point. (Primary power on mains terminals, no power on inverter terminals).

Panel Switches

Mode - TMU

Chronometer - Standby

Override - Off

Relay K2 is not activated since there is no 240 V on inverter terminals of PPT-1A.

(i) K2/1 makes to connect chronometer time marks to TMU (secondary timing).

(ii) K2/2 changes over to connect inverter power (which is now on mains terminals) to recorder motors (Primary power).

(iii) K2/3 breaks to disconnect EMI time mark (K3/2) from TMU input.

Note - In this situation there is no automatic back-up power for the recorder motors if the inverter fails; if this situation is likely to apply for long periods of time it is suggested that a 240 V relay (activated by inverter power) be placed in the recorder motors line to connect the mains power on failure of the inverter.

(b) Sync pulse fails - EMI timing is OK

If the EMI 230 V output can carry the load then plug the PPT-1A primary power plug into the 230 V power point on the EMI and disconnect the sync pulse from the inverter. The situation is now equivalent to normal ((1) above).

If the sync pulse and the EMI 230 V output have failed, which is likely (230 V output is the amplification of the sync pulse), then decide whether the unsynchronised inverter power is better or worse than the mains supply. The criterion is stability of frequency, provided that the inverter frequency is between 49.5 and 50.5 Hz; the frequency is generally very stable and can be easily adjusted to 50 Hz by observing the period of the square wave from the inverter oscillator or the period between the triggering spikes that change the state of its bistable circuit (Plate 10).

(i) If inverter power is chosen the operation is identical to the normal operation (1).

(ii) If mains power is chosen; connect PPT-1A primary power plug into mains power point and PPT-1A mains power plug into the inverter power point. Now we have mains power on inverter terminals and inverter power acting as a back up on mains terminals. The operation is again as normal.

3. TMU failure (Primary power, mixed timing)

The chronometer provides the magnetic time mark (through the 5 minute program) and EMI provides the seismic time mark.

Panel Switches

Mode - Direct

Chronometer - Standby

Override - Off

The mode switch on direct connects the chronometer 5 min contacts to time-mark relay K1 and K1/1 time-mark to magnetic time line while K3/2 (EMI) time mark becomes connected to the seismic time line.

4. Inverter failure

On inverter failure K2/2 changes over to provide mains power to motors and K2/2 breaks to disconnect EMI from TMU while K2/1 makes to connect chronometer time mark to TMU. Turn override switch (S3) on to connect EMI time-mark (K3/1) to TMU and re-establish primary timing.

5. TMU and EMI simultaneous failures

This emergency situation is a combination of 2 and 3.

A decision has to be made between using the inverter or mains power as in 2. Once that is done the panel switches are in both cases:

Mode - Direct

Chronometer - Standby

Override - Off (Override has to be off, otherwise chronometer 5 - minute time mark will not get to magnetic time lines)

Chronometer NTO-1 Relay - On

With Mode on direct the 5 min chronometer time-mark (K1/1) is connected to the magnetic time lines, and (provided the NTO-1 relay is switched on), the chronometer 1 min closures make across the seismic lines; however, there will be no hour identification on the seismograms.

Note - At all other times the NTO-1 relay must be switched off.

APPENDIX 2

Operation of Synchronised Inverter

(Refer to the circuit diagram in Plate 10)

The input to the pulse transformer T2 is a 50 Hz 3-4 V P-P square wave. This wave should be clean, and free of internal spikes.

The wave-form at the output of the transformer (TP1) is illustrated in Figure A. This output is half-wave rectified by MR9, and at the junction of C10, R15 and MR9 (TP2) the wave-form is a series of 50 Hz negative spikes as illustrated in Figure B.

These spikes are differentiated by C10 and R15, and are seen at TP3 (the base of VT5) as shown in Figure C. The positive edge of these spikes triggers VT5. The negative part of the spikes is kept at -0.7 V by diode MR20 across R21, and the positive part of the spikes is at +0.7 V through the action of the base-emitter junction of VT5.

The wave-form at the collector of VT5 is a series of 10 V negative spikes spaced at 20 ms when the synchronising wave from the clock is on. They represent the triggering of VT5, by the half-wave rectified spikes coming out of the transformer T2.

When the unijunction (VT3) is not conducting, C6 and C14 commence to charge via R10, RV1 and RV2. When the potential of the VT3 emitter reaches the firing potential, the unijunction triggers and C6 and C14 discharge via the base-emitter junction and R8. The potential at the emitter subsequently drops and the unijunction cuts off: C6 and C14 commence to charge again and the cycle repeats. This is how the unijunction functions when it is free-running. At its emitter (TP5) observe a series of capacitor charge close up discharge voltage curves as shown in Figure E1. The point to note is that all voltage curves peak at the same voltage.

The triggering of VT5 by synchronising spikes results in 10V negative pulses at collector of VT5 which become 1V negative pulses at base b2 of the unijunction, and they reduce the unijunction firing potential. This means that C6 does not have to charge up to about 7.5 V (as in Figure E1) in order for the unijunction to trigger. If the emitter of the unijunction is between 6.5 - 7.5 V at the arrival of the 1 V negative sync spike at base b2, the unijunction will conduct i.e. the firing of unijunction will sync with the input waveform.

In order to obtain a 50 Hz wave out of the bistable circuit we need 100 positive spikes per seconds (Figure G) i.e. the unijunction has to conduct 100 times per second. So, for the output 50 Hz square wave to be completely in sync with the incoming wave, 100 synchronising spikes per second need to arrive at the unijunction base b2. This is not the case, because the spikes (Figure A) at the output of transformer T2, are only half wave rectified. It is for this reason that when the sync is in operation that the C6 charge/discharge voltage curves do not peak at the same voltage (Fig. E2); only the alternate ones peak at the same voltage i.e. half the unijunction firings are due to sync pulses, while the other half are due to the unijunction selftriggering. This means that the output wave (Figure H) has the same periodicity (20 ms) as the input wave, but its mark to space ratio is not unity.

Procedure for synchronising the inverter

The inverter will not synchronise if its free-running frequency is too low or too high for the synchronising wave, and its frequency has to be changed by means of the potentiometers RV1 and RV2.

If the inverter is not synchronising the noise given out by the output transformer is not uniform - there are periodic fluctuations in the tone of the noise due to periodic firing of the unijunction by sync pulses that arrive at the right time. In between these periodic sync firings the unijunction is self-triggering over a number of cycles and the sync pulses are seen separately as shown on Figure F2. By changing the setting of potentiometers RV1 or RV2, the gradual absorption of sync pulses by the self trigger pulses (i.e. sync pulses get closer and closer to the trigger pulses) is observed and synchronisation is obtained when the wave form at TP6 is as in Figure F1. This means that the inverter's free-frequency has been adjusted close to the synchronising frequency.

The inverter will synchronise only if its frequency is equal to or not more than 3 Hz lower than the sync frequency. Since the inverter frequency does drift, it is advisable to set the frequency in about the middle of this range. To do this look at waveform E2.

After observing wave form F1, proceed to look at waveform E2, and then adjust the fine frequency potentiometer until the difference between successive peaks is between 0.2 V - 0.3 V. This puts the inverter frequency at the top end of the synchronising range and gives a mark to space ratio close to one.

Note (1) If the difference between successive peaks is 1 V then the inverter is free-running a lot lower than the sync frequency and is at the bottom of sync range, and if there is no difference in successive peaks (but synchronisation on) inverter frequency is exactly equal to the synchronising frequency.

(2) For the inverter to have any chance of synchronising, its own frequency has to be less than or equal to the synchronising frequency. Also note, if the action of VT4 is removed, through VT4 failing or sync pulse being turned off, the inverter will speed up.

TABLE 1

MAGNETOGRAM PARAMETERS

Component	Scale value (a) Obs'd	Adopted	SD	Temp Coeff nT/°C	Parallax correction(s)
Normal run					
D	2.37	2.37	0.01		
H	19.43	19.45	0.05	3.0	negligible
Z	20.82	20.80	0.05	0.0	
T(z)		1.38			
Rapid run					
D	1.00	1.00	0.01		+ 01
H	5.33	5.35	0.03		+ 26
Z	6.34	6.35	0.04		+ 32

(a) Sd in min/mm; Sh, Sz in nT/mm; St in °C/mm

TABLE 2

NORMAL-RUN MAGNETOGRAM BASELINE VALUES 1975

(NO CORRECTION)

COMPONENT	DATE	BASELINE	REMARKS
D	1 DEC 1974 00	27° 07.2'	
	25 JAN 1975 00	27° 06.3'	RECORDER ADJUSTMENT
	7 FEB 00	27° 07.5'	" "
	23 FEB 00	27° 06.6'	" "
	28 APR 1600	26° 28.7'	NEW RECORDER
H	1 DEC 1974 00	12653 nT	
	6 JAN 1975 00	12647 nT	RECORDER ADJUSTMENT
	23 FEB 00	12591 nT	USING LOWER BASE
	25 FEB 00	12647 nT	USING UPPER BASE
	16 MAR 0300	12591 nT	USING LOWER BASE
	17 MAR 0100	12647 nT	USING UPPER BASE
	20 MAR 0000	12591 nT	USING LOWER BASE
	28 MAR 0200	12647 nT	USING UPPER BASE
	7 APR 0000	12591 nT	USING LOWER BASE
	8 APR 0500	12647 nT	USING UPPER BASE
	12 APR 0100	12591 nT	USING LOWER BASE
	16 APR 00	12647 nT	USING UPPER BASE
	17 APR 00	12591 nT	USING LOWER BASE
	28 APR 1600	12653 nT	NEW RECORDER
Z	1 DEC 1974 00	63787 nT	
	28 APR 1975 1600	63784 nT	NEW RECORDER
Bt(Z)	1 DEC 1974 00	-61.9°C	

TABLE 3

PRELIMINARY MONTHLY MEAN VALUES 1975

MONTH 1975	H nT	D EAST ° '	Z nT	K INDEX
January	12859	27 39.2	-63941	2.82
February	12856	27 39.7	-63938	3.33
March	12852	27 40.5	-63933	3.26
April	12853	27 41.0	-63929	2.75
May	12847	27 41.6	-63935	2.41
June	12843	27 42.7	-63929	2.11
July	12840	27 43.6	-63926	2.23
August	12840	27 44.5	-63922	2.13
September	12840	27 45.4	-63918	1.94
October	12843	27 46.1	-63915	2.25
November	12842	27 46.8	-63918	2.91
December	12845	27 47.9	-63909	2.25
MEAN	12847	27 43.3	-63926	2.53

TABLE 4

ORIENTATIONS OF VARIOMETER MAGNETS (NORTH POLES)

Component	H	D	Z
Normal-run	E 0.6°N	N 0.5°E	N 0.4°Down
Rapid-run	W 1.5°S	N 1.3°E	N 1.1°Down
Reference fields	12 845 nT	27.75°E	-63 920 nT

TABLE 5

GEOMAGNETIC ANNUAL MEAN VALUES 1963-1975

YEAR	D	I	H	X	Y	Z	F
	° '	° '	nT	nT	nT	nT	nT
1963	26 08.5	-78 24.2	13193	11843	5813	-64294	65634
1964	26 17.0	-78 24.7	13174	11812	5834	-64249	65586
1965	26 28.6	-78 25.5	13152	11773	5864	-64214	65547
1966	26 37.6	-78 26.7	13121	11729	5881	-64175	65503
1967	26 46.5	-78 28.5	13084	11681	5894	-64166	65486
1968	26 54.7	-78 29.7	13053	11639	5908	-64132	65447
1969	27 02.3	-78 30.8	13026	11602	5921	-64099	65409
1970	27 09.6	-78 32.1	12996	11563	5932	-64078	65383
1971	27 13.3	-78 33.3	12963	11527	5930	-64032	65331
1972	27 22.1	-78 34.4	12937	11489	5947	-64808	65302
1973	27 27.6	-78 35.8	12905	11451	5951	-63985	65273
1974	27 34.3	-78 37.6	12865	11396	5951	-63956	65235
1975	27 43.3	-78 38.2	12847	11372	5976	-63926	65204
Mean annual change	+7.8'	-1.2'	-29.7	-39.8	+13.7	+29.9	-35.2

TABLE 6

ELECTRICAL EARTH CONNECTIONS

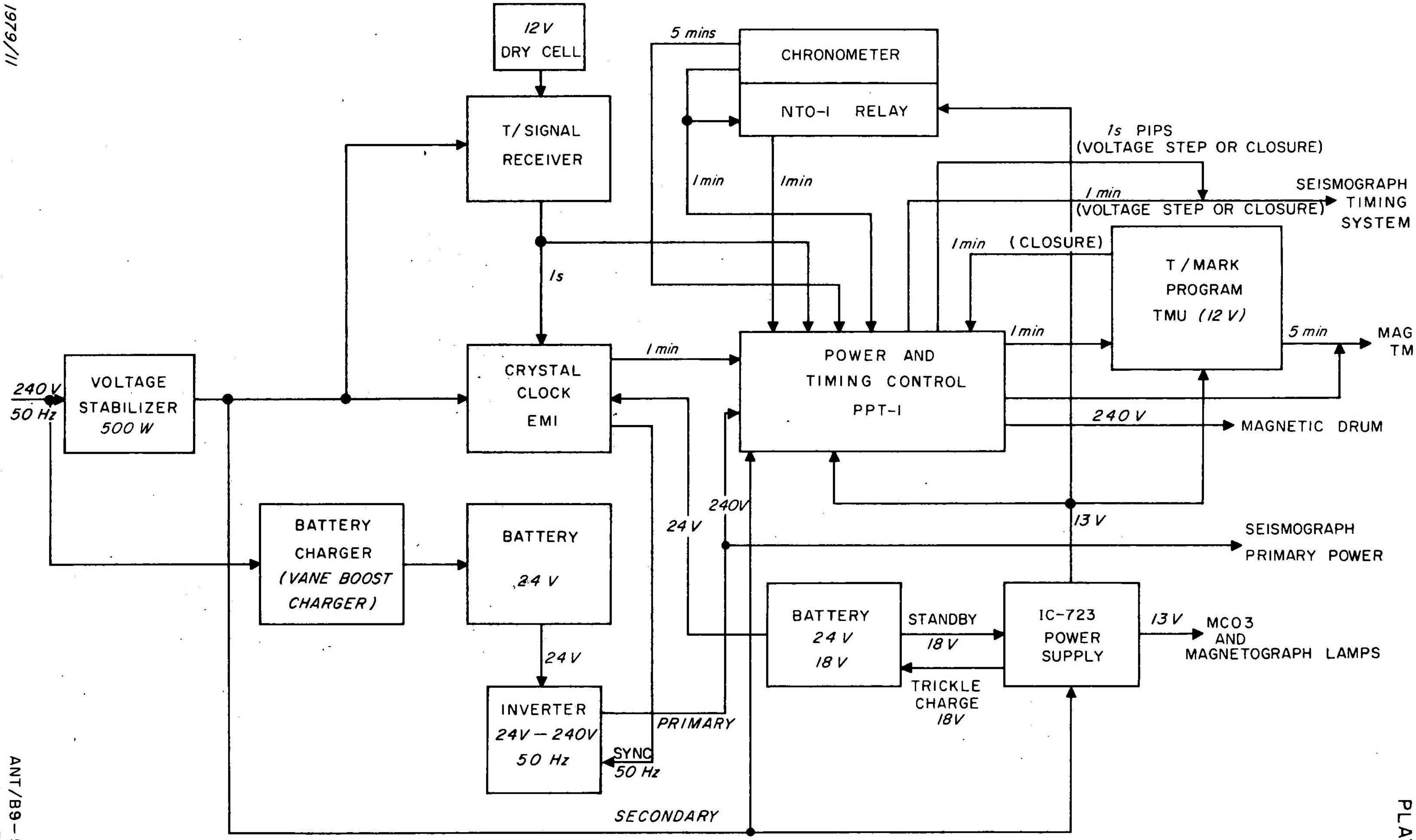
EARTH POINTS	NATURE OF EARTH CONNECTION	REASON
EMI chassis	AC plug	Safety and shielding
Negative rail of EMI's internal power supply.	Joining pins 10 and 8 on rear connector. Pin 10 is chassis.	4V 50 Hz sync pulse to inverter needs to be earthed, to prevent pickup.
Negative rail and chassis of IC-724 power supply.	Direct connection to earth terminals on the office wall.	Prevents interference to PPM in absolute hut.
Shield of cable to seismic hut.	Direct connection to earth terminals on the office wall.	Prevents interference to 50 Hz signal to seismograph recorder motors.
Negative rail of standby 24V to EMI clock and IC-723 power supply.	Connected to earth through negative rail of IC-723 and EMI's DC supply which are earth.	
Panel of PPT-1A	Negative rail of IC-723 connected directly to panel.	Prevents pick up in PPT-1A.
Radio Chassis	AC - plug	Safety and shielding
Positive rail of 12V external supply to radio	Through radio circuit.	

TABLE 7

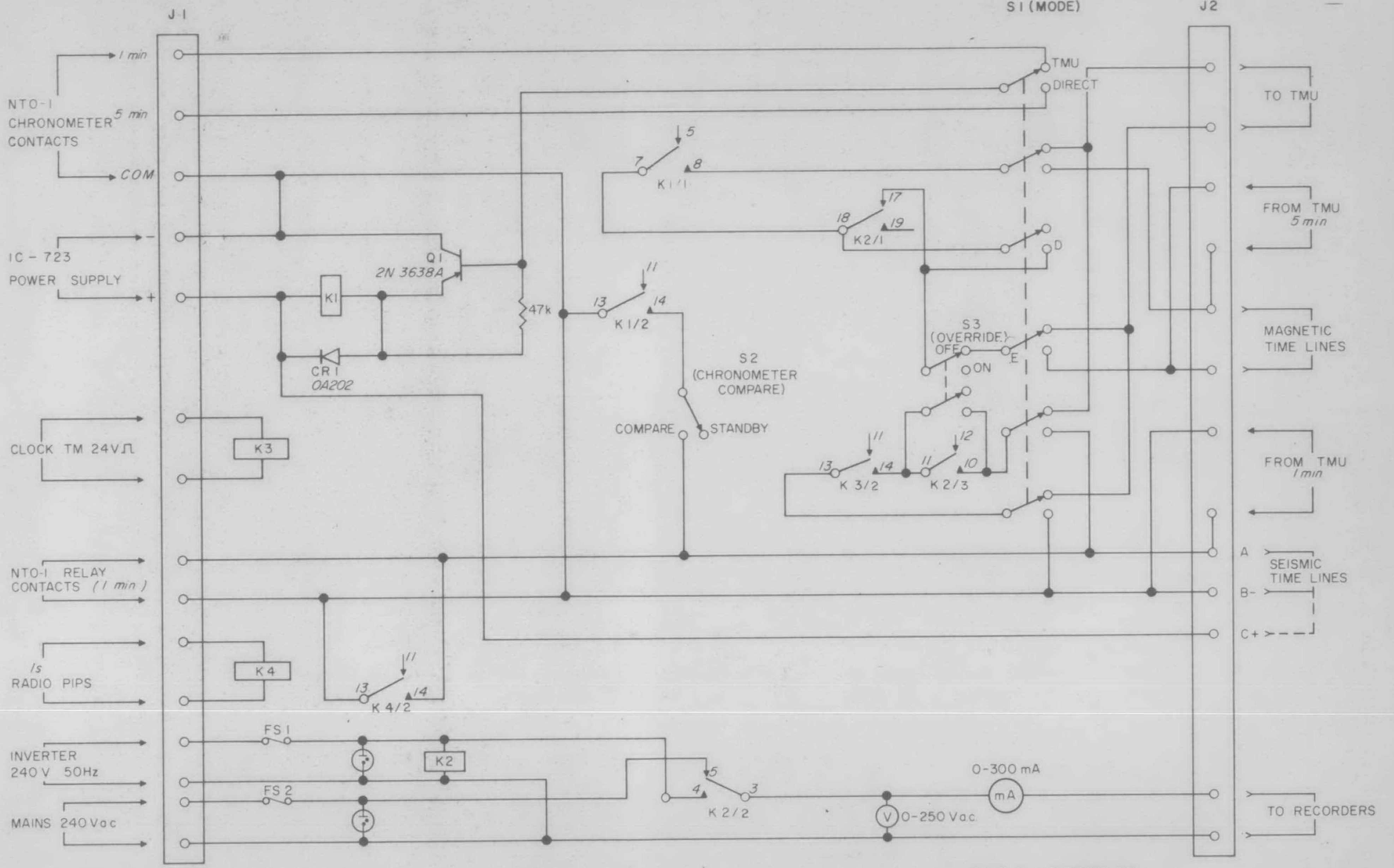
FELT EARTHQUAKES 1975

DATE	TIME UT		MM INTENSITY
	h	m	
Feb 10	10	30	II
Jul 21	20	59	II-III

CENTRAL POWER AND TIMING ARRANGEMENTS
(1975 Revision)



POWER AND TIMING CONTROL PPT-1A

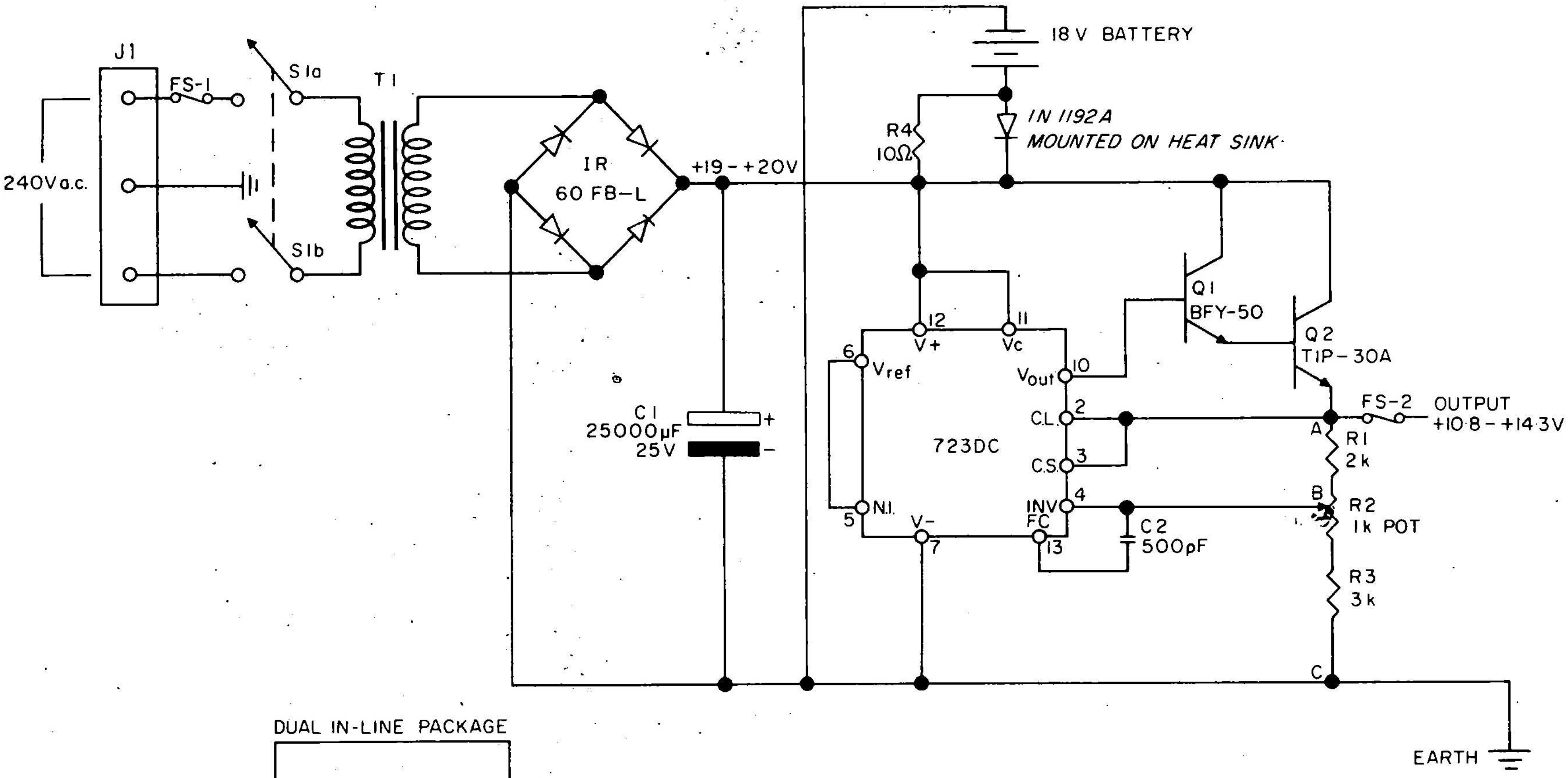


(A, B-) — CLOSURE TM

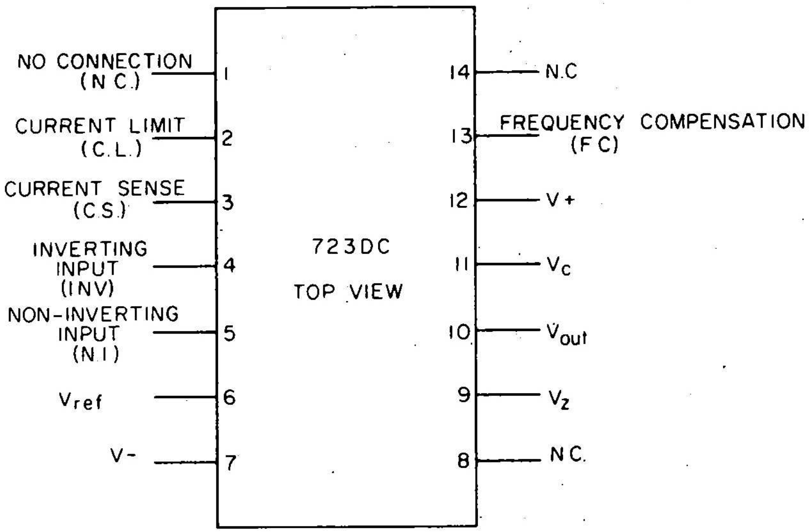
(A, C+) — VOLTAGE STEP TM

K2 RELAY SHOWN WITH INVERTER POWER OFF

IC-723 POWER SUPPLY



DUAL IN-LINE PACKAGE



<u>SPECIFICATIONS</u>

$$V_{out} = 7 \cdot 2 \times \frac{(R_{AB} + R_{AC})}{R_{BC}}$$

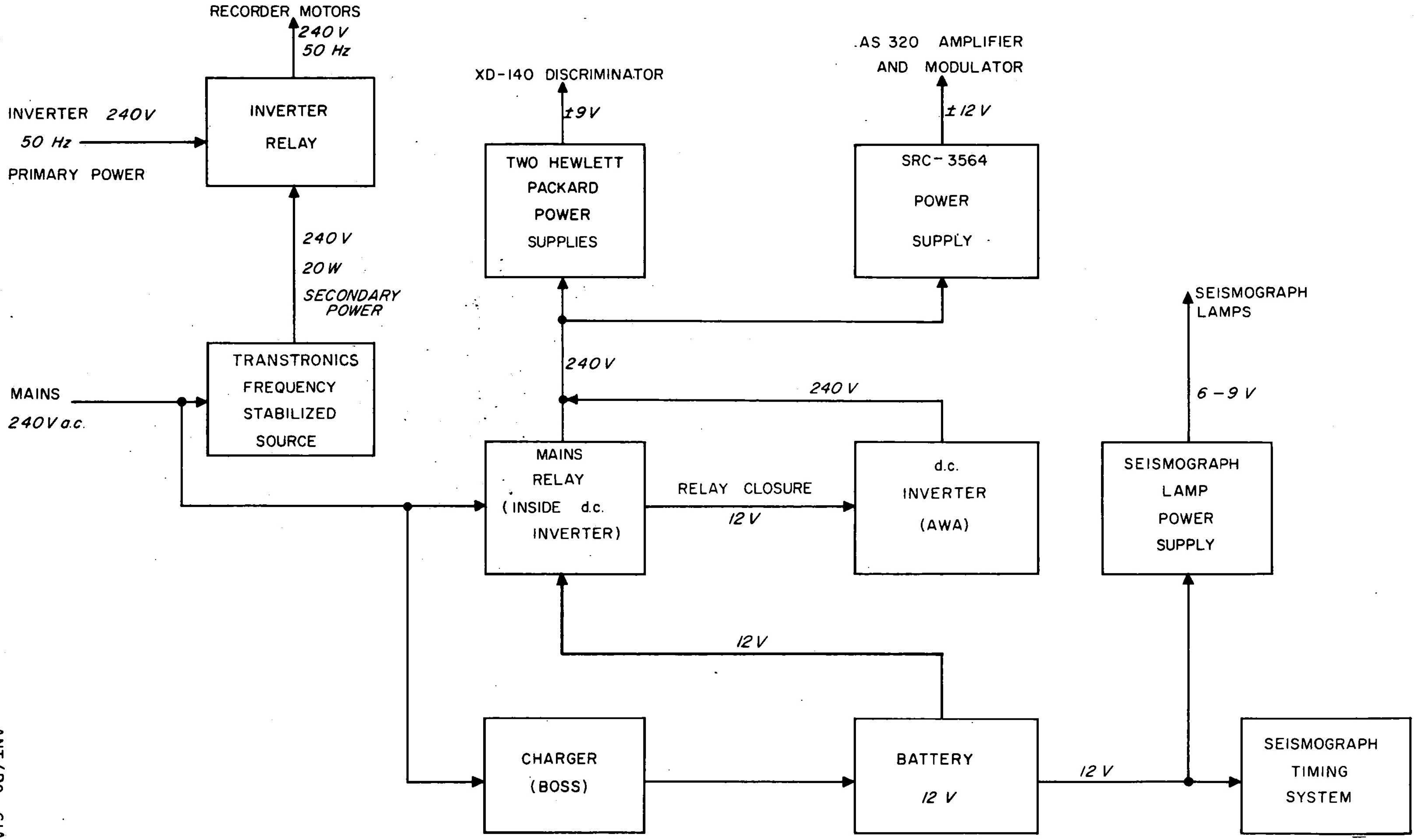
$$(V_{in} - V_{out})_{min} = 3 \cdot 7 \text{ V}$$

FOR $\Delta I_{Load} = 1\text{A}$ $\quad \Delta V_{out} = 15\text{mV}$

FOR $\Delta V_{in} = 1\text{V}$ $\quad \Delta V_{out} = 1 \cdot 5\text{mV}$

CURRENT CAPABILITY IS 4A

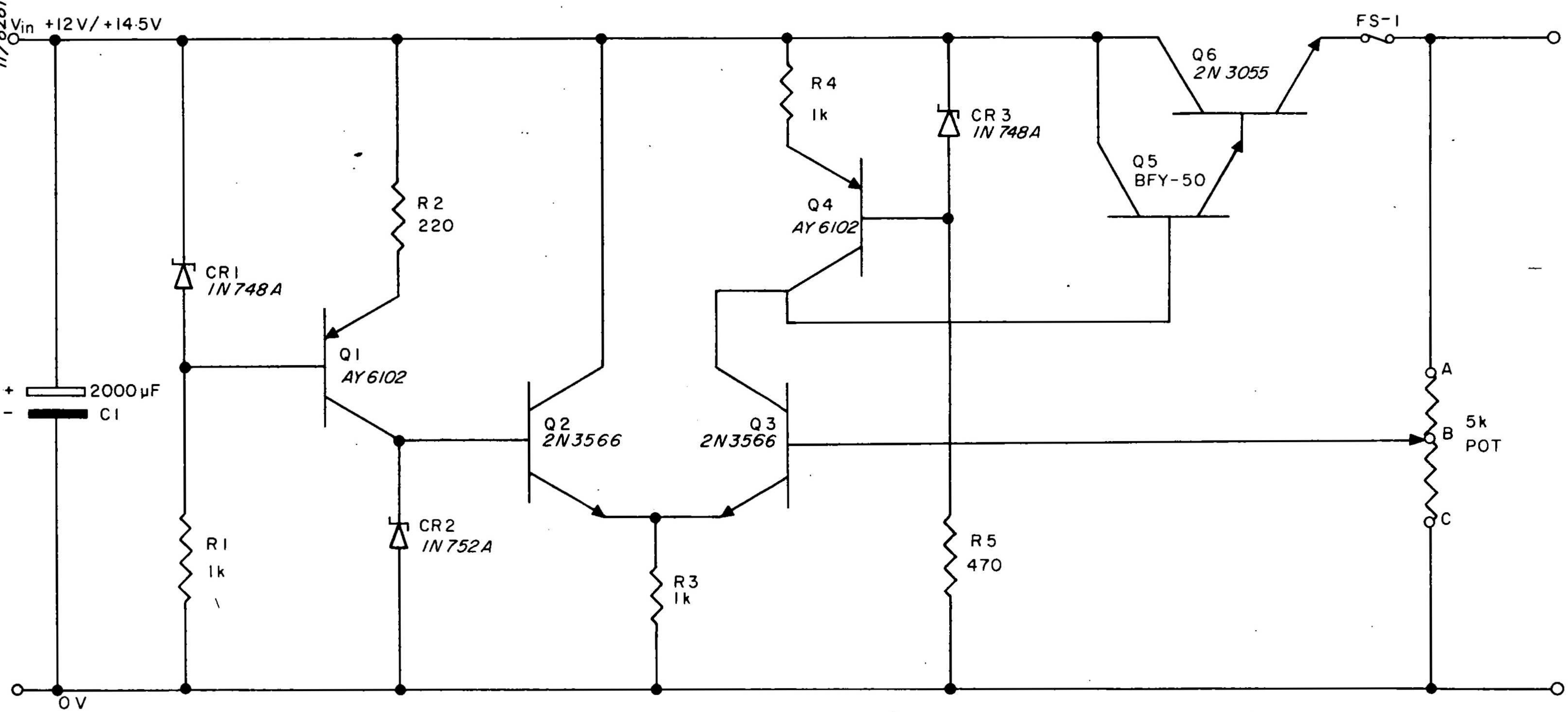
SEISMOGRAPH POWER SYSTEM
(LOCATION – SEISMOGRAPH VAULT)



ANT/B9-61A

PLATE 4

SEISMOGRAPH LAMP SUPPLY



SPECIFICATIONS

$V_{out} = 5{\cdot}6 \times 5k / R_{BC}$

$(V_{in} - V_{out})_{min} = 4{\cdot}2V$

FOR $\Delta I_{Load} = 1A$ $\Delta V_{out} = 20 mV$

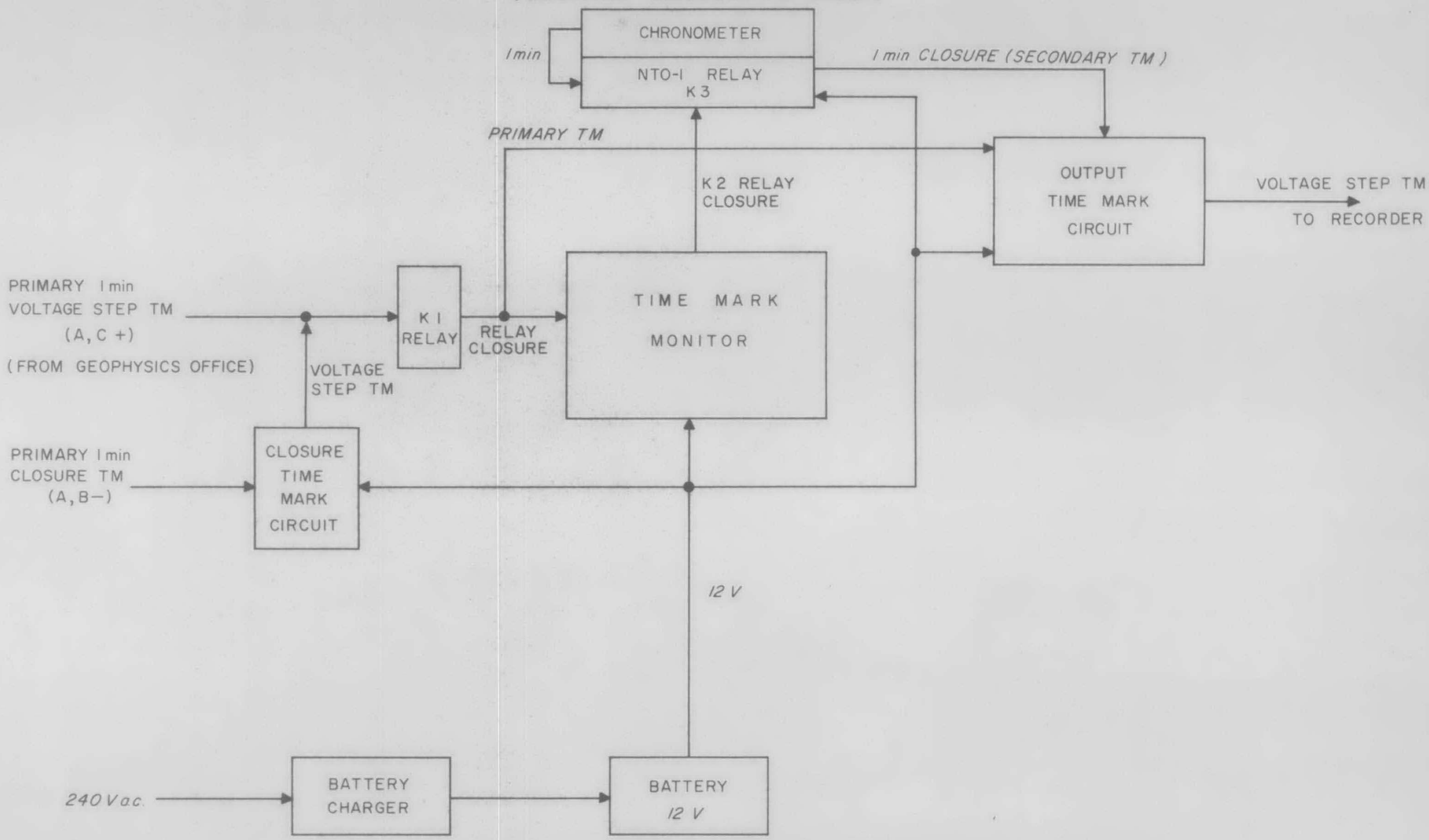
FOR $\Delta V_{in} = 6V$ $\Delta V_{out} = 10 mV$

CURRENT CAPABILITY IS 3A

ANT/B9-62A

Record No. 1979/11

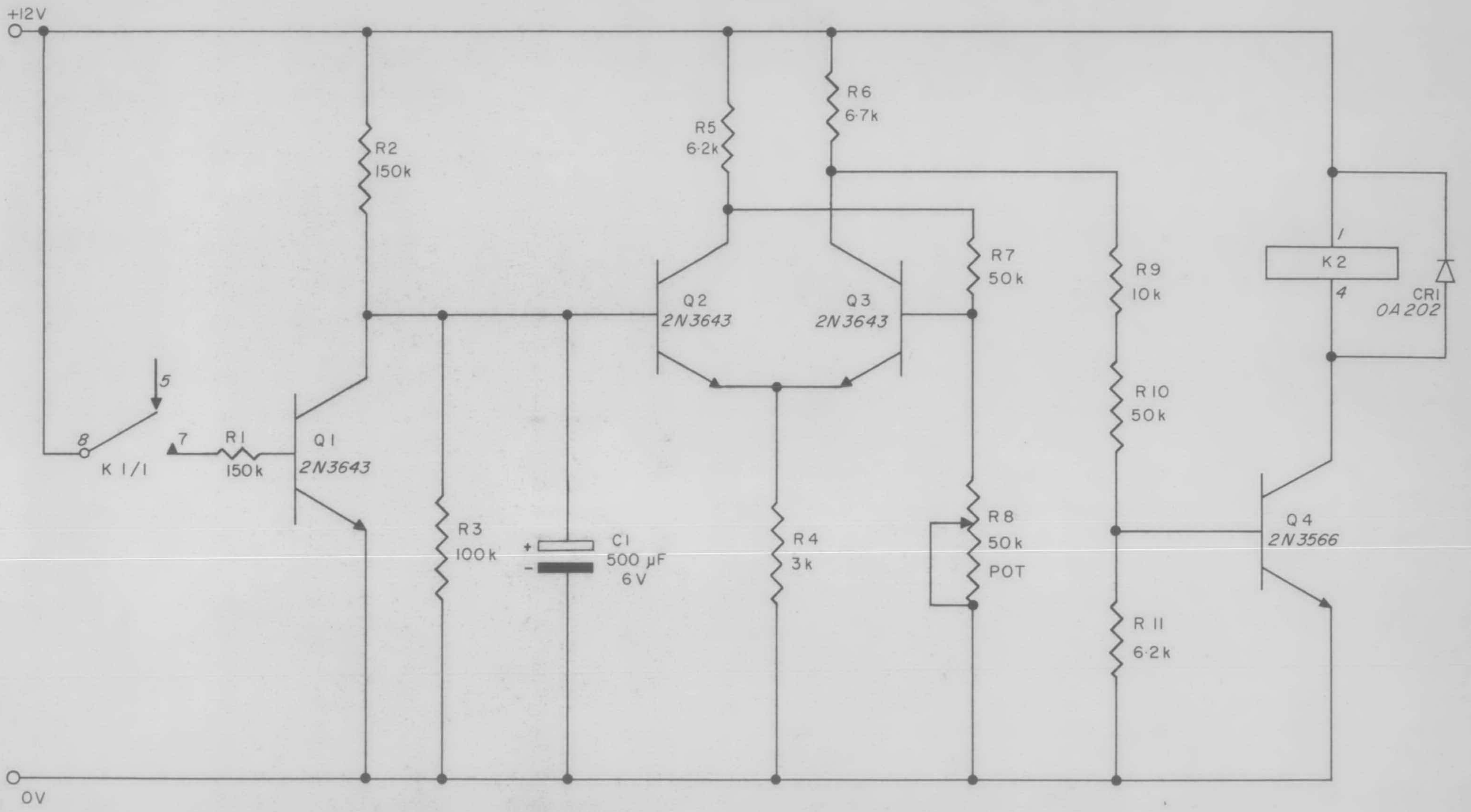
SEISMOGRAPH TIMING SYSTEM
(LOCATION - SEISMOGRAPH VAULT)



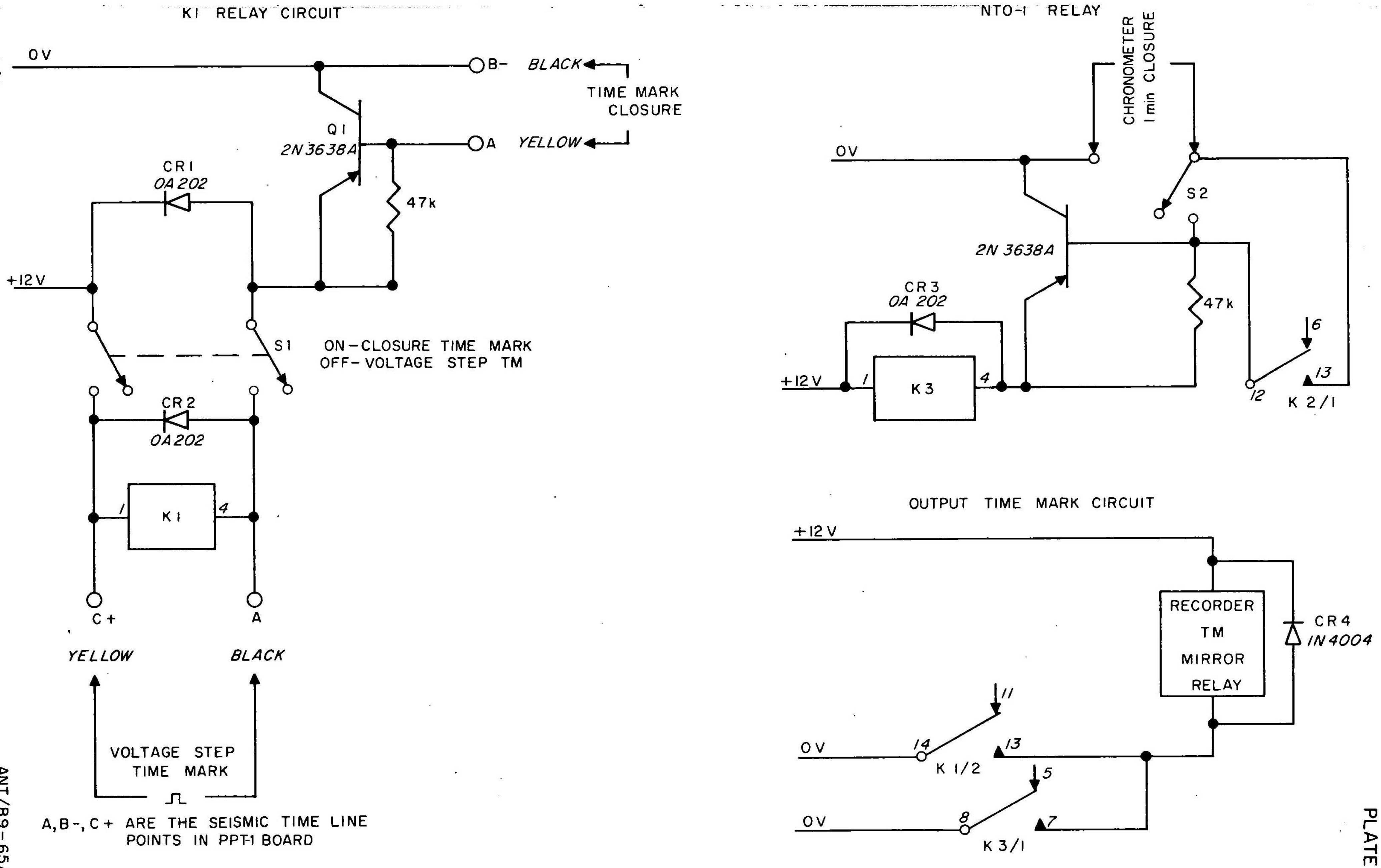
ANT/B9-63A

PLATE 6

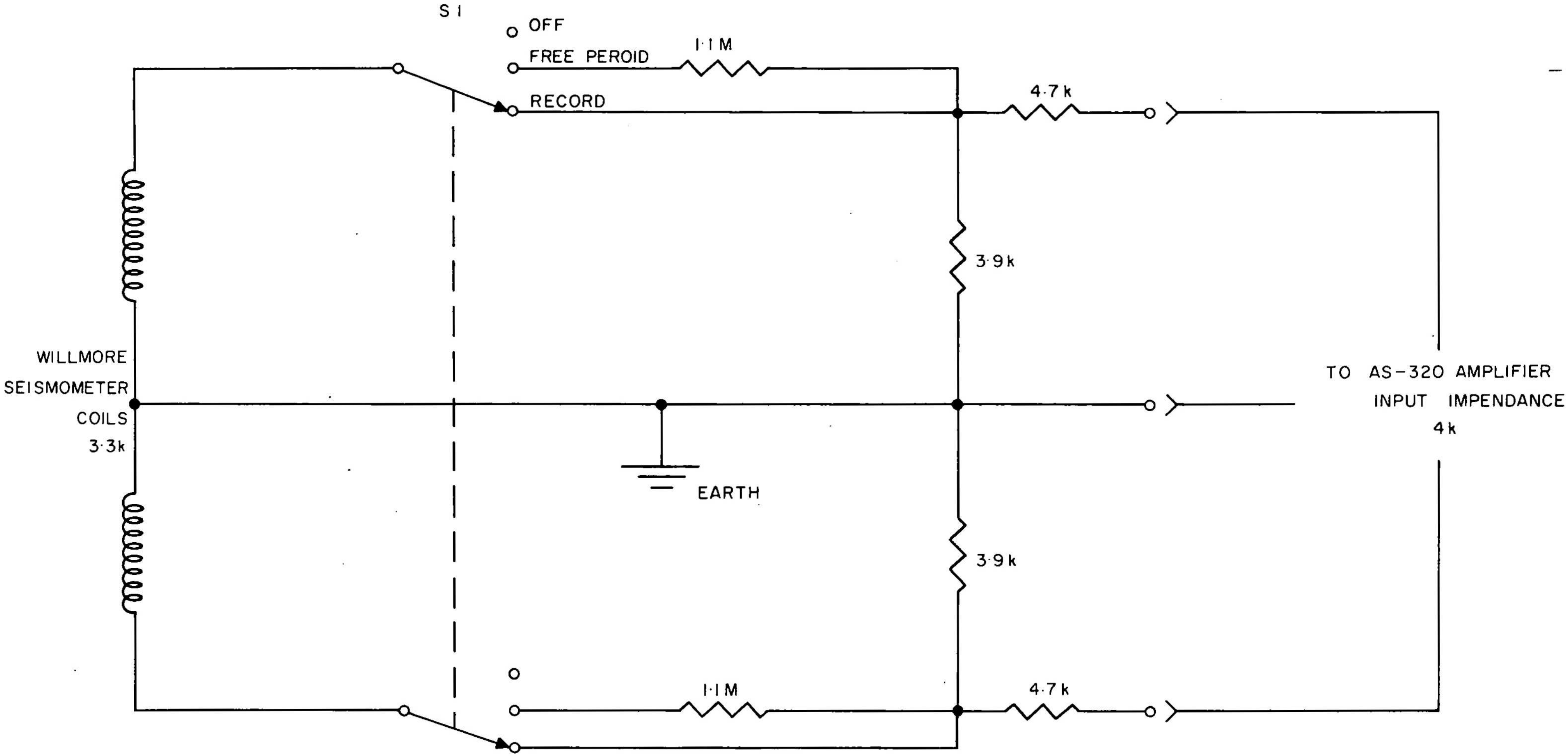
SEISMOGRAPH TIME MARK MONITOR

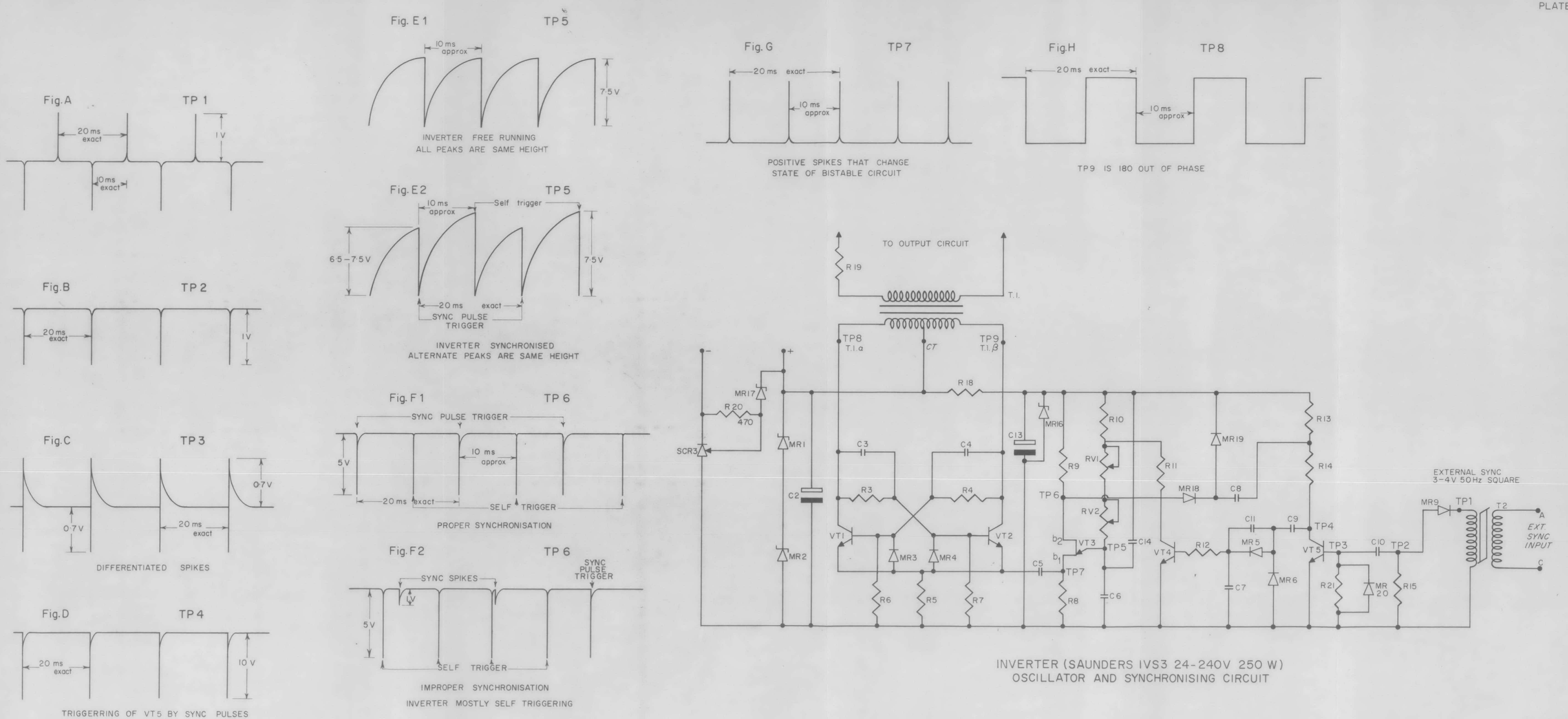


SEISMOGRAPH TIMING RELAY CIRCUITS

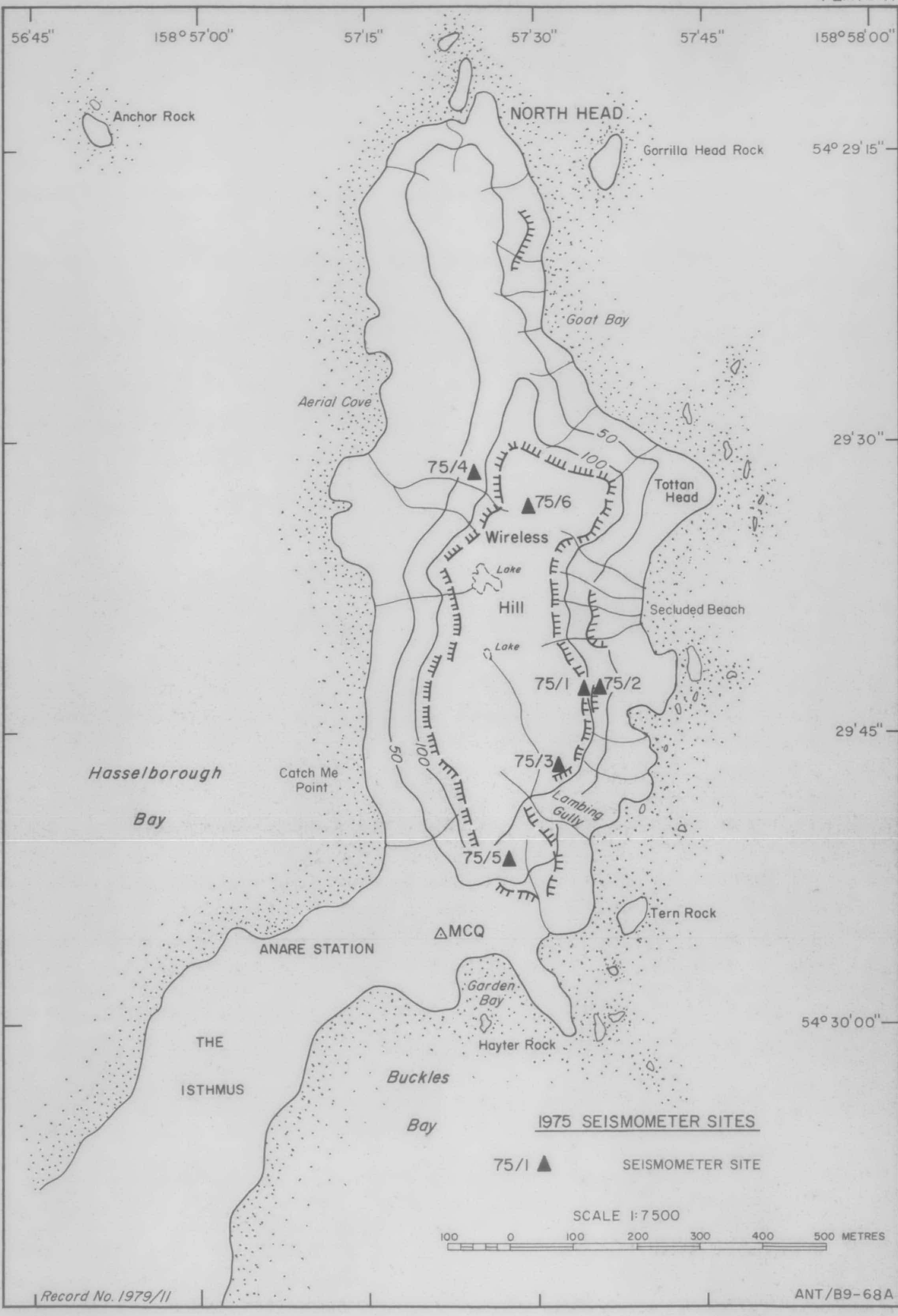


SEISMOMETER CONTROL PANEL
(LOCATION - SEISMOMETER PIT)





INVERTER (SAUNDERS IVS3 24-240V 250 W)
OSCILLATOR AND SYNCHRONISING CIRCUIT


56'45"
158° 57'00"
57'15"
57'30"
57'45"
158° 58'00"
Anchor Rock
NORTH HEAD
Gorrilla Head Rock
54° 29'15"
Goat Bay
Aerial Cove
29'30"
50
100
75/4
75/6
Tottan Head
Wireless
Lake
Hill
Secluded Beach
Lake
75/1
75/2
29'45"
75/3
Hasselborough
Catch Me Point
Bay
Lambing Gully
75/5
Tern Rock
MCQ
ANARE STATION
Garden Bay
54° 30'00"
THE
ISTHMUS
Hayter Rock
Buckles
Bay
1975 SEISMOMETER SITES
75/1 SEISMOMETER SITE
SCALE 1:7500
100 0 100 200 300 400 500 METRES
Record No. 1979/11
ANT/B9-68A