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GRID-CARD CALIBRATOR

A part of the electronic model
for tides and storm surges

S. Ishiguro
1980

NATURAL ENVIRONMENT RESEARCH COUNCIL
INSTITUTE OF OCEANOGRAPHIC SCIENCES

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INSTITUTE OF OCEANOGRAPHIC SCIENCES

INTERNAL REPORT 67

G R I D - C A R D C A L I B R A T O R

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CONTENTS

ABSTRACT

The electronic model for tides and storm surges contains a large number of 'grid cards' which solve the dynamic equations without step-by-step processes. The time-independent variables of the equations are set in each grid card, while the time-dependent variables are fed into it from another circuit. Described in this paper is an apparatus which facilitates the setting of the former, as well as testing and adjusting the card itself.

1. INTRODUCTION

The electronic model of tides and storm surges contains a large number of 'grid cards' which solve the dynamic equations. All the grid cards are electrically and physically identical, but controls on each card have to be calibrated individually according to the values of geophysical parameters of the sea to be modelled. Described in this paper is an apparatus, called 'the grid-card calibrator', which facilitates such a calibration, as well as testing and adjusting the card itself.

The description of the grid cards itself is minimized in this paper, since this is described in detail in a separate paper (Ref. 1).

Note The principle of the 'grid card' is an original idea (patented). Although this part is an electronic analogue circuit in the sense of being non-digital, this is not related to an analogue computer consisting of operational amplifiers with feed-back elements. Digital techniques have been applied to the rest of the model system.

2. OUTLINE OF THE GRID CARDS

Fig. 1 shows an equivalent circuit (greatly simplified) of a 'grid card'. This is essentially a 5-terminal circuit with a 'grid centre' (O). Each of the four circuit branches (N-O, E-O, S-O, W-O) has an inductive element, resistive element, and electromotive-force element. The electromotive-force element generates three types of voltage:

<u>a</u> a voltage related to the current through the adjacent branch,

<u>b</u> a voltage which controls the total resistance of its own branch, and

<u>c</u> a voltage controlled by an external signal.

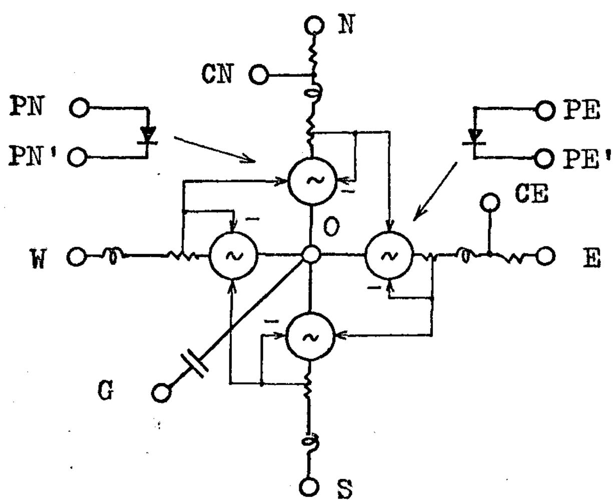
<u>c</u> is fed into the grid through an opto-electronic terminal (PN-PN') or (PE-PE'), so that the signal source and the grid are electrically isolated. <u>c</u> is omitted from branches (S-O) and (W-O).

Branch (G-O) has a capacitive element, and terminal (G) is used for a common conductor throughout the grids. In order to measure the current through branches (N-O) and (E-O) respectively, terminals (CN) and (CE) are prepared.

The circuit elements in a grid card are operated by +5V and -5V power supplies taking their voltage references to the grid centre (O), not the common conductor (G). These voltages are obtained through an electronic voltage-divider which has two input terminals for 10V DC. This 10V DC is supplied from an electrically isolated (or 'floating') power supply.

Consequently, each grid card has 16 terminals. Each grid also has 5 pre-set controls for compensating the manufacturing deviations of the electronic components, and 10 controls for geophysical parameters. The former should be adjusted only once when the grid card is assembled, and the latter should be adjusted for each model sea.

All the grid cards are electrically and physically identical (a printed circuit board of 6 × 10 cm^2 with a 16-pin edge connector).



<u>Fig. 1</u> Equivalent circuit (greatly simplified) of a 'grid card'.

3. SCHEME OF THE GRID-CARD CALIBRATOR

The grid-card calibrator has been designed to facilitate:-

1 checking a newly assembled grid card,

2 adjusting the preset controls of the card so that the manufacturing deviations of its components are compensated, and

3 setting each parameter control on the card to a particular value.

Therefore, the calibrator consists of several different circuits, but these are combined into one unit so that the whole operation becomes simple, and the operation is carried out in the correct order.

The grid card includes two inductors. The checking and calibration of these inductors can be carried out independently from the rest of the circuit by a conventional inductance meter, and therefore these are not included in the grid-card calibrator.

The rest of the calibrations are:-

P Zero voltage of the floating power supply,

OS Offset adjustments for four amplifiers,

F N and E components of external forces,

Ωe N, E, S, W components of the Coriolis parameter, and

R E and S components of the bottom friction coefficient.

Fig. 2 shows the schematic diagram of the grid-card calibrator which carries out the above calibrations. Note, the essential part of the circuit for each type of calibration is shown separately in this figure, while the actual circuit is not separated.

Throughout the 5 types of calibration, a common principle is used:- A voltage (DC or a triangular waveform) is fed into a standard circuit and to a circuit under calibration, simultaneously. The outputs of the two circuits are displayed on a CRO screen. Then, the circuit under calibration is adjusted so that the outputs become equal in their waveforms and magnitudes. A DC voltage is used for P and OS, and a triangular voltage is used for the rest of the calibrations. In practice, the two output voltages under comparison are electronically switched with a much shorter period than the period of the triangular voltage, so that the calibration is independent from external circuits, including the CRO.

In Fig. 2, the output voltage from the circuit under adjustment is represented by e_1, and that from the standard circuit by e_2.

P and OS (Top section of Fig. 2)

The calibration of P and OS is selected by SW2. For P, the potential at z is adjusted by r_v so that $e_1 = e_2$ = zero. For OS, the potential at Q is adjusted by r_o so that $e_1 = e_2$ = zero.

F (2nd section of Fig. 2)

A triangular voltage, whose amplitude can be adjusted by VR5, is supplied from point b to both a grid card under test (through a voltage to current-convertor) and to the standard-voltage circuit (directly). A constant DC current (10mA) is superimposed on the triangular wave, in order to bias the photo-electric coupler in the grid card. The standard output voltage, e_2, is set by a digital potentiometer, VRS, and a decade selector SW3 (x1 or x0.1).

Ω_e (3rd section of Fig. 2)

The output current of the triangular voltage flows through r_a of the grid card under test and R27 or R28. The voltage drop across r_a produces e_1, and the voltage across R27 or R28 produces e_2. e_2 is set by the VRS and selector SW3 (x1 or x10). This calibration circuit has been designed to minimise the errors due to the common mode voltage appearing at the input terminals of the grid card under test; i.e. R27 (or R28) > r_a, and R27 = R10 (or R28 = R11).

R (Bottom section of Fig. 2)

The E (or S) component of a grid card and the W (or N) component of its adjacent grid card in E (or S) direction are connected in series, and r_a (E) or r_a (S) in the first grid card is adjusted so that the total series resistance is equal to R. For this calibration, a bridge circuit is formed by the two grid cards (in a series connection) and three other standard resistances, which give

$$R = \frac{R22}{R21 \text{ or } R23} \times VRS$$

when $e_1 = e_2$. The decade can be selected by SW2. Each grid card contains an inductor, L(W) or L(N), in series with the resistors under calibration but this does not affect the values of resistance since the period of the triangular voltage is chosen much greater than the time constant of inductive circuit.

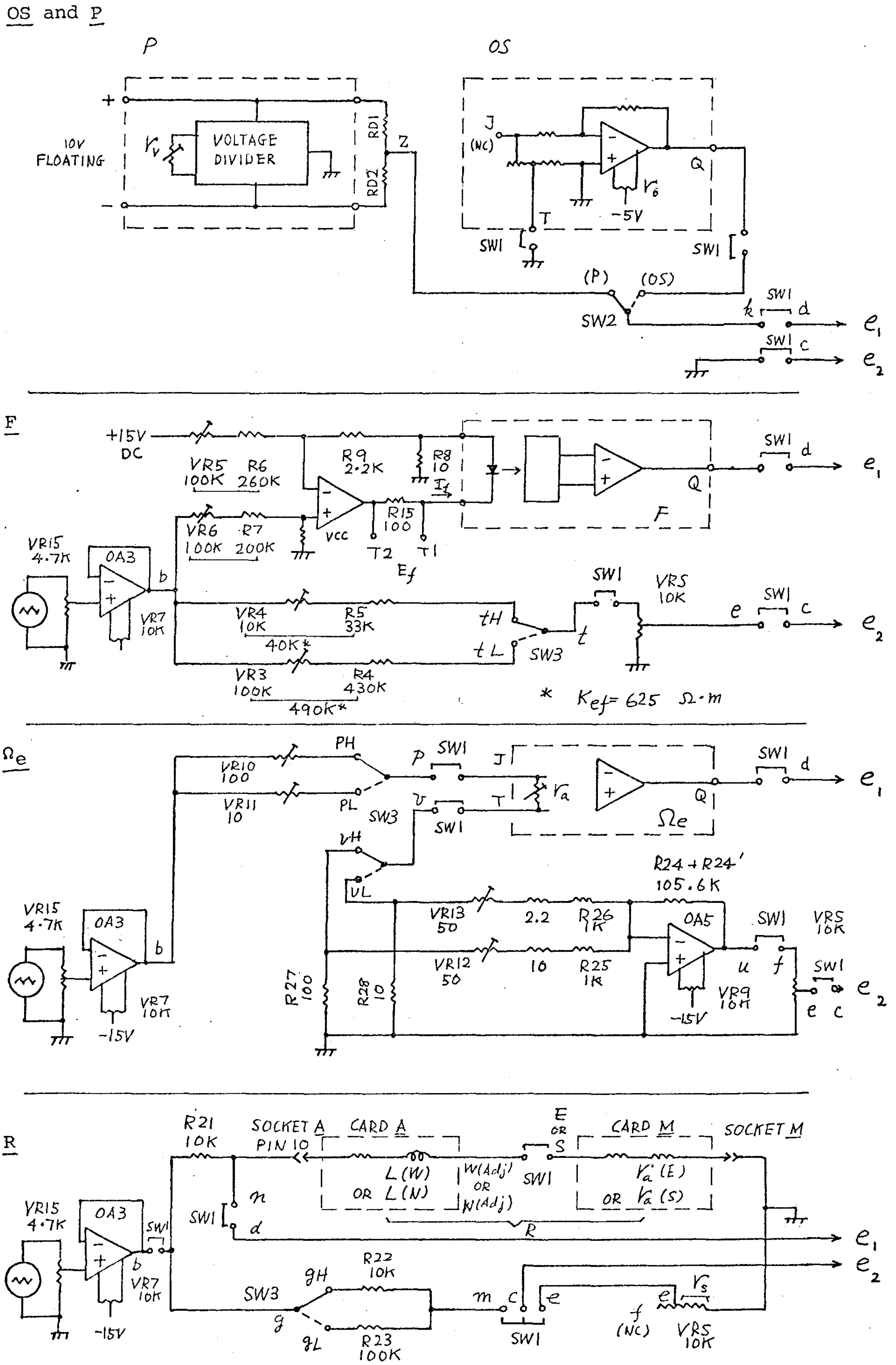


Fig. 2 Schematic diagram of the grid-card calibrator. The circuit for each parameter is shown separately.

4. CIRCUIT DESCRIPTION

Fig. 3 shows the circuit diagram of the grid-card calibrator which is a combination of four types of circuit shown in Fig. 2. The selection of different calibrations (12 combinations in all, including directional variations) is carried out by the main selection switch, SW1, which is shown by a table in Fig. 3.

Standard values for the calibrations are kept by a digital potentiometer, VRS, and several other semi-fixed resistors.

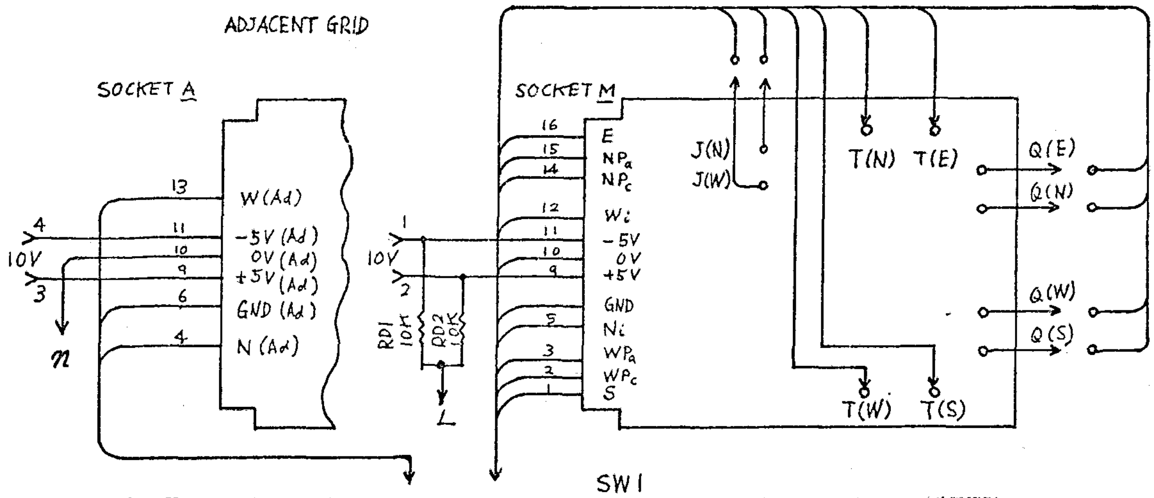
A square-wave voltage is generated by OA1, and is converted into a triangular voltage by OA2. The frequency of these waveforms is adjusted by VR1, and the amplitude of the triangular waveform by VR15 (from zero to 5V pk-pk). The triangular voltage is passed through a buffer amplifier OA3, whose output impedance is of the order of 1Ω. This output is fed into several measuring circuits at b.

OA4 is a voltage-to-current converter for calibration F̲. OA5 is a buffer circuit for calibration of Ωe. The two output voltages, e_1 and e_2, are connected to an external CRO through a CMOS analogue switch (DG200) which is driven by a square-wave voltage generator consisting of OA6 and 04. The switching frequency can be changed by VR8. A part of the square-wave voltage is supplied to the CRO for synchronization.

Fig. 4 shows the simplified circuit diagram of the power supply unit for the grid-card calibrator. This supply unit has four different output voltages (all regulated): +15V, -15V and two independent 10V supplies. The first two supplies are used for driving the grid-card calibrator itself. The last two 10V supplies are used for a grid card under calibration, and for a grid card representing 'Adjacent Grid'. Each of the last two supplies is connected to an AC power line through an 'Isolation Transformer' which has a very high grade of AC/DC isolation. All the four DC voltage regulators are the same type, except for their output voltages.

Both the isolation transformer and DC-voltage regulator are the same types as those used for the actual 'Main Computation Network', and they are specially developed for this purpose. See a separate paper (Ref. 1) for their details.

Table 1 shows the circuit connections of the grid-card calibrator.



POSITION \ BANK			1	2	3	4	5	6	7	8	9
1	OS	N	T(N)	Q(N)	a	0V	k				
2		E	T(E)	Q(E)	a	0V	k				
3		S	T(S)	Q(S)	a	0V	k				
4		W	T(W)	Q(W)	a	0V	k				
5	F	N	T(W)			e	Q(W)		WPc	q	t
6		E	T(N)			e	Q(N)		NPc	q	t
7	Ω_e	N		v	T(N)		Q(N)	c	p	J(N)	u
8		E		v	T(E)		Q(E)	c	p	E	u
9		S		v	T(S)		Q(S)	c	p	S	u
10		W		v	T(W)		Q(W)	c	p	J(W)	u
11	R	E		b	g	m	n	m	E	W(Ad)	
12		S		b	g	m	n	m	S	N(Ad)	
WIPER			0V	└──	──┘	c	d	e	└──	──┘	f

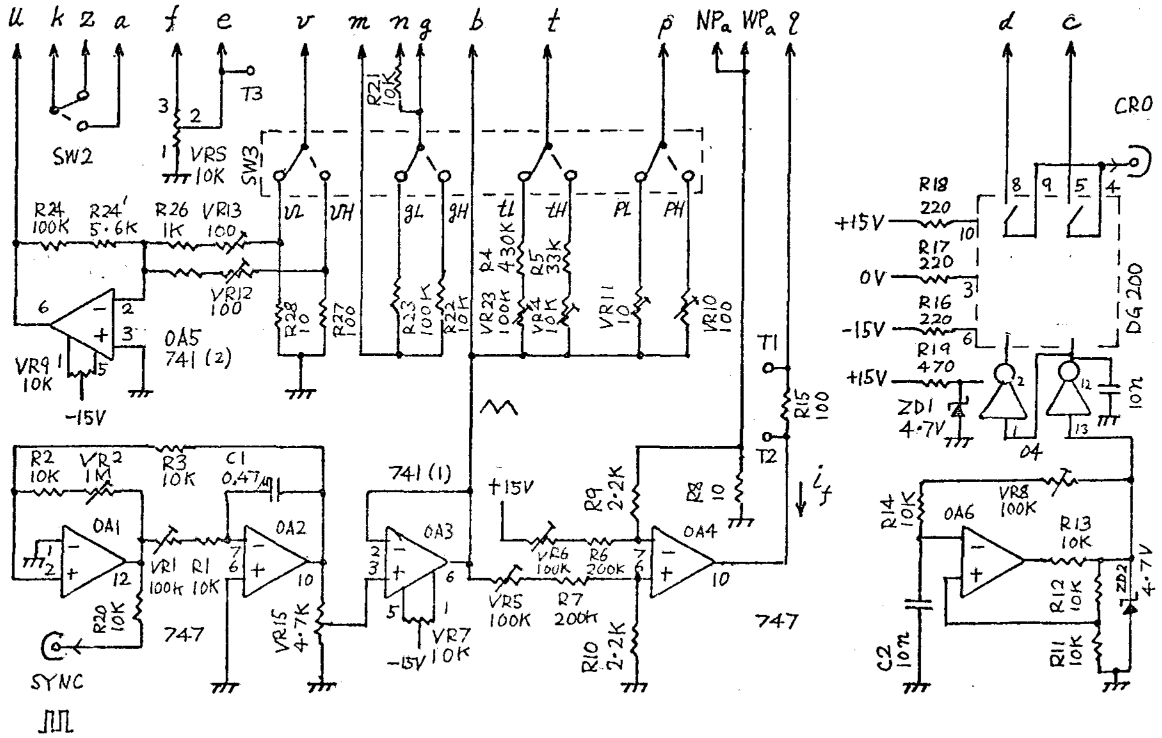


Fig. 3 Circuit diagram of the grid-card calibrator.

Table 1 Circuit connections of the grid-card calibrator.

From		To	Wire colour
SCO	Pin 1 (-5V)	Socket M Pin 11	Be
	2 (+5V)	9	R
	6 (OV)	10	Gn
	3 (+5Va)	Socket A Pin 9	Gr/R
	4 (-5Va)	11	Gy/Be
	(OVa)	10	Gy/Gn
	7 (+15V)	BD15 +15V	V
	5 (-15V)	-15V	Gy
	6 (OV)	OV	Gn
Connector	CRO	BD15 CRO	V(Sleeve)
Connector	SYNC	BD15 SYNC	Y
SW1	S	Socket M Pin 1	W
	WPc	2	W/Be
	WPa	3	W/R
	Ni	5	W/Or
	GND	6	Gn
	Wi	12	W/Gn
	NPc	14	W/Be
	NPa	15	W/Gy
	E	16	W/Bk
	Q(E)	Test lead Q(E)	Or/Bn
	Q(N)	Q(N)	Or/R
	Q(W)	Q(W)	Or/Gn
	Q(S)	Q(S)	Or/Bk
	T(S)	T(S)	R/Bn
	T(E)	T(E)	R/Gn
	T(N)	T(N)	R/Be
	T(W)	T(W)	R/Bk
	J(N)	J(N)	Gn/Bn
	J(W)	J(W)	Gn/R
	N(A)	Socket A Pin 4	Gy/Bn
	W(A)	13	Gy/Or
	GND	6	Gn
	a	SW2 a	Y/R
	k	k	Bn/Be
	z	z	Or/Bn
	p	SW3 p	R/Gy
	g	g	Or/Be
	v	v	Be
	t	t	W/R
	b	BD15 b	Or
	c	c	Bn(Sleeve)
	d	d	Be(Sleeve)
	q	q	W
	m	BD16 m	Gn/Be
	n	n	Gn/Y
	u	u	Y/Gn
SW3	pH	BD16 pH	R/Bn
	pL	pL	Bn/Be
	gH	gH	Or/R
	gL	gL	Gy/Be
	vH	vH	Or/Gn
	vL	vL	W/Bn
	tH	tH	Y
	tL	tL	R

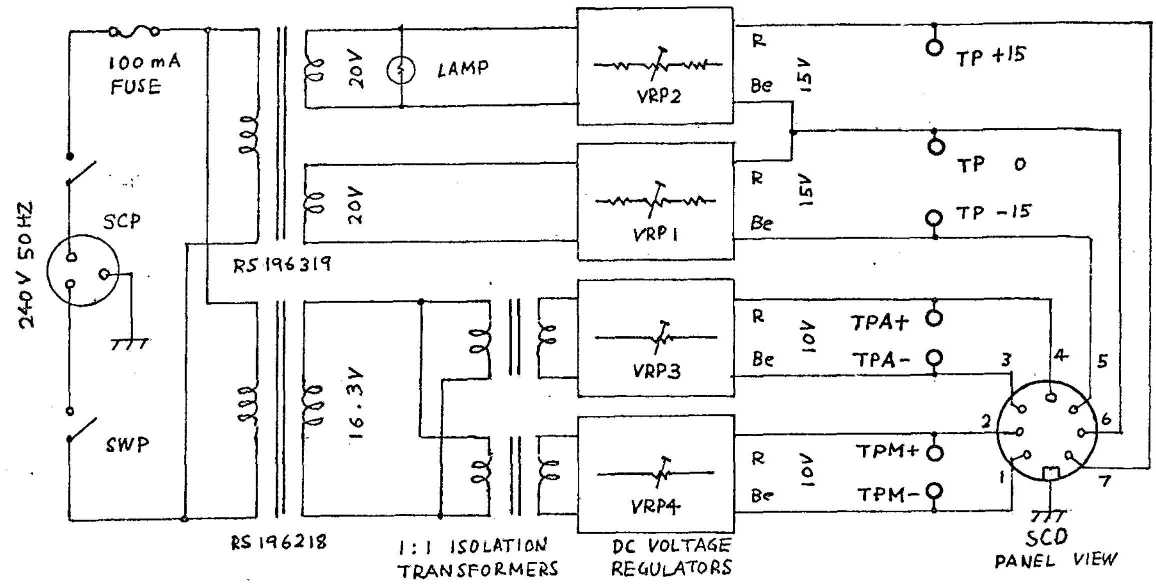


Fig. 4 Simplified circuit diagram of the power supply unit for the grid-card calibrator.

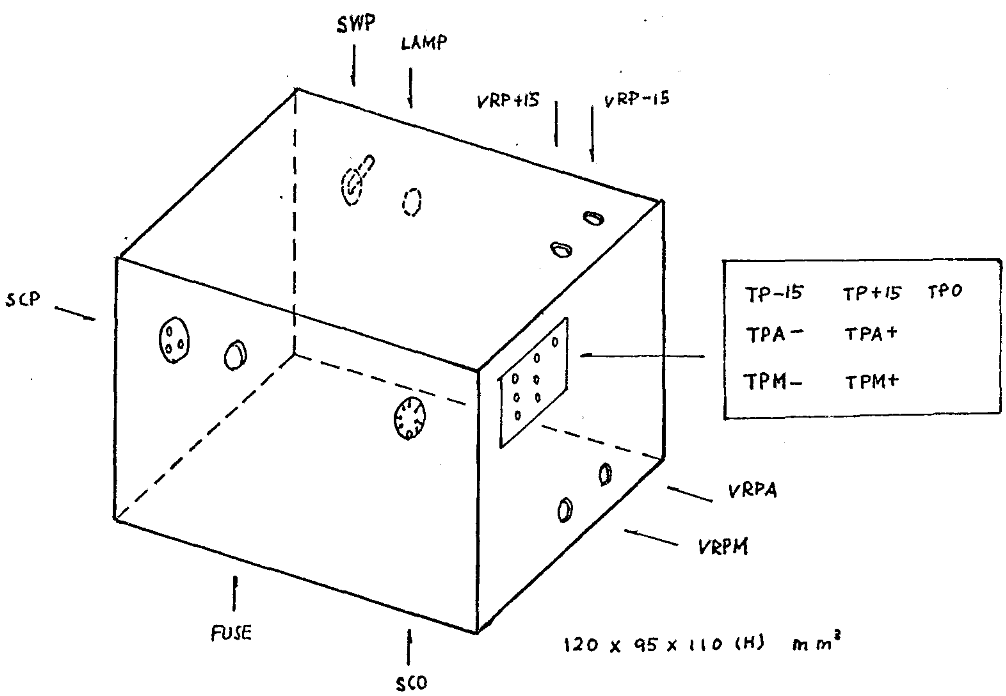


Fig. 5 Physical arrangement of the power supply unit for the grid-card calibrator.

5. PHYSICAL ARRANGEMENT

Fig. 5 shows the physical arrangement of the power supply unit for the grid-card calibrator. This consists of two combined aluminium-diecast boxes which work as a heat sink. The positions of controls, connectors, switches, test terminals are shown in the same diagram.

Fig. 6 shows the grid-card calibrator with a grid card under calibration, and Fig. 7 shows its details. The grid card under calibration is connected to a 16-pin edge connector on the top of the calibrator. There are some test terminals also on the top of the calibrator. The grid card representing an 'Adjacent Grid' is connected to the same type of edge connector which is on the side of the calibrator case.

The function selection switches and digital standard potentiometer are arranged on the front panel of the case. The connectors for a CRO and power line are arranged on its rear panel.

The test terminals and controls of the calibrator are arranged on the bottom of the case, and the controls are usually sealed.

Fig. 8 shows the details of component arrangement inside the case. The components are arranged on two printed circuit boards.

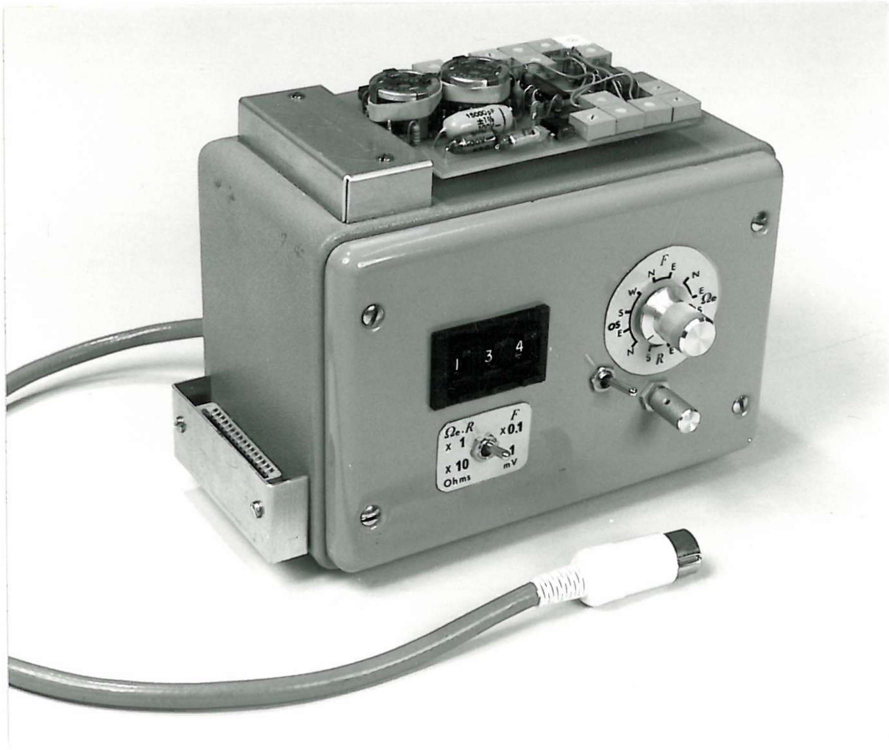


Fig. 6 Grid-card calibrator with a grid card under calibration

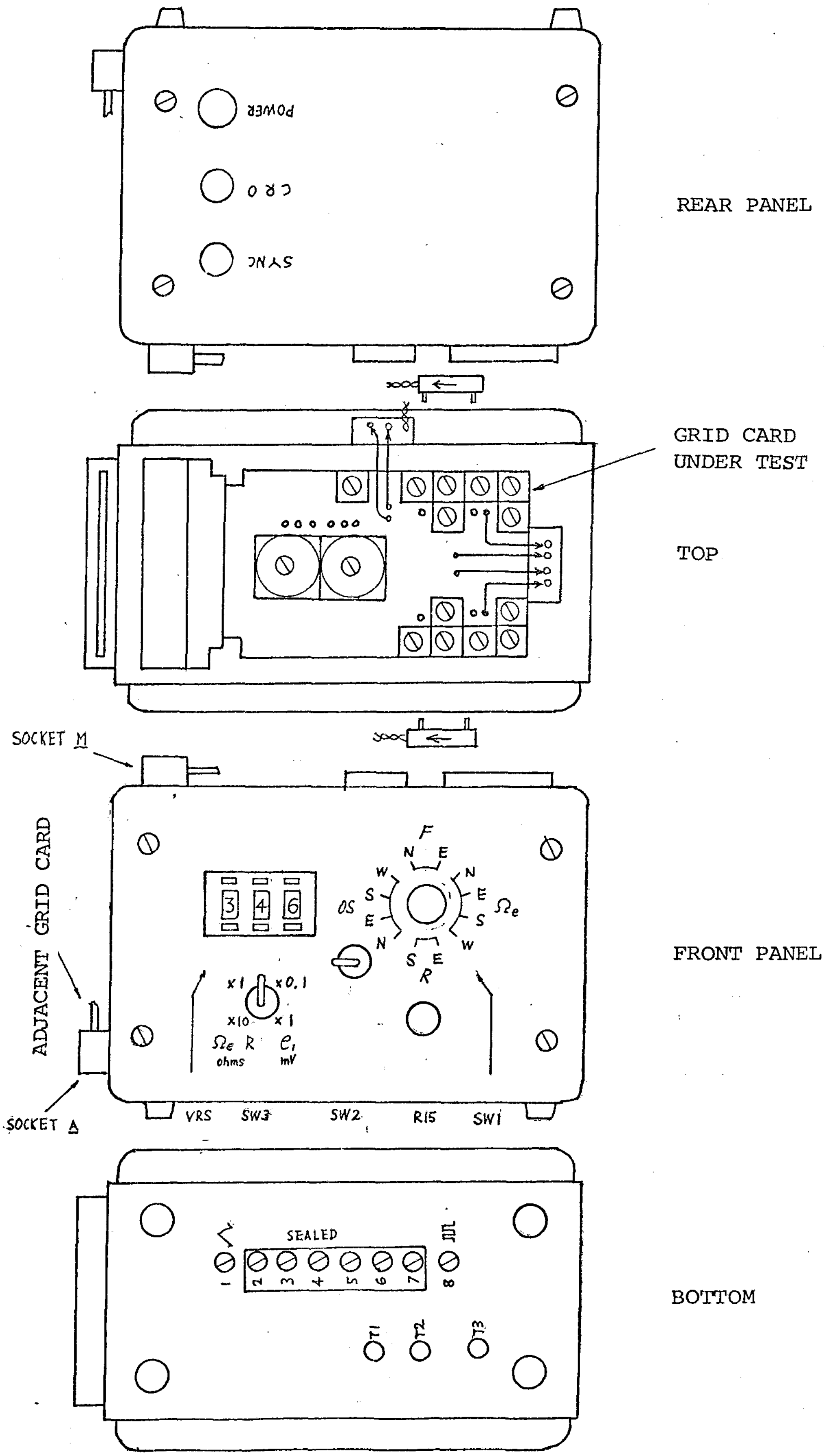
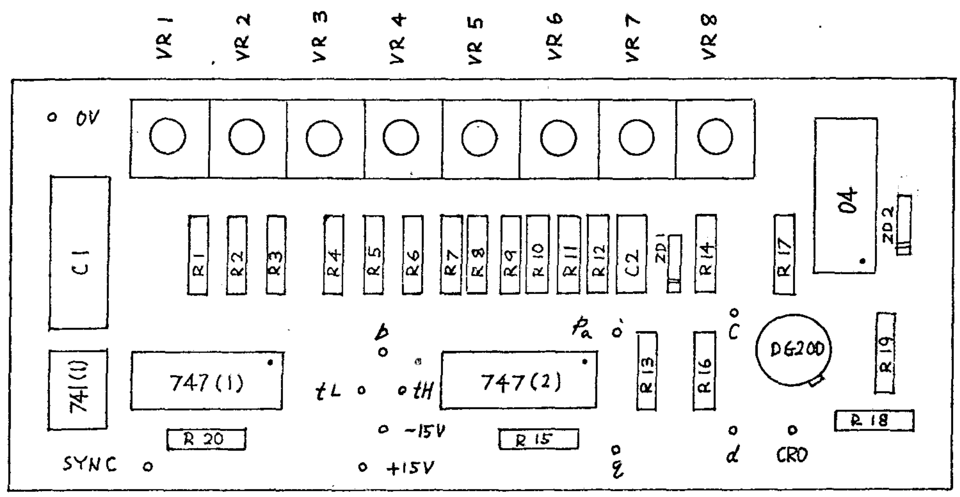
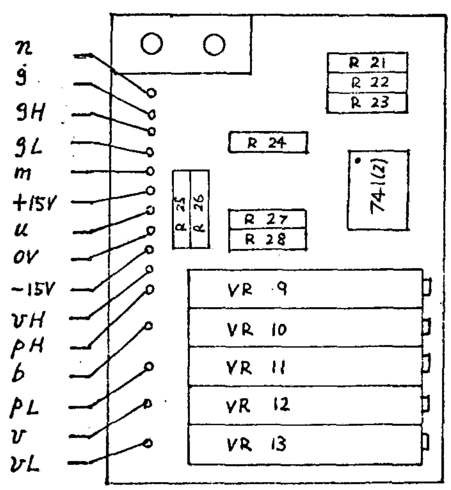


Fig. 7 Details of the grid-card calibrator, outside (scale 1/2).

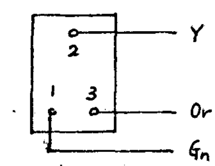


BD15

BD16



VRS(10K)



SW3

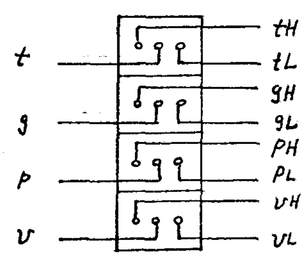


Fig. 8 Details of the grid-card calibrator, inside (full scale).

6. INITIAL ADJUSTMENTS

When the grid-card calibrator is assembled, initial adjustments of the calibrator itself are necessary. Note, the accuracy of values set for all grid cards depends on the accuracy of the grid-card calibrator. The adjustments should be carried out in the order described in this chapter.

1. Power supply voltages

Floating DC power supplies (two channels) for two cards	10.007V (each channel)
Power supplies for the calibration circuit	+15.00V -15.00V

The voltages should be measured at the test terminals on the power supply case, when the calibrator with two cards is connected.

2. Standard resistors

Standard values in all the calibrations are kept by the standard resistors described in this paragraph. All the standard resistors should have temperature coefficients better than ±100ppm/°C.

(a) Each of the following standard resistances should have a tolerance better than ±1% of the nominal value (shown in brackets), and also each set of resistances should have a ratio shown with a tolerance better than ±0.05%.

$$\frac{RD1\ (10K)}{RD2\ (10K)} = 1.000$$

$$\frac{R21\ (10K)}{R22\ (10K)} = 1.000$$

$$\frac{R21\ (10K)}{R23\ (100K)} = 0.1000$$

$$\frac{VR10\ (100\Omega)}{VR11\ (10\Omega)} = 10.00$$

(b) Each of the following standard resistances should have a tolerance better than ±0.5% of the nominal value shown.

R15 = 100Ω

R9 = R10 = 2.2K

R8 = 10Ω

(c) Each of the following resistances should be stable to better than ±0.05% of the value preset by the calibration procedures.

VR3 + R4

VR4 + R5

VR5 + R6

VR6 + R7

$$\frac{R24 + R24'}{R28 + VR13 + R26} \text{ and } R28,\ VR11$$

$$\frac{R24 + R24'}{R25 + VR12 + R25} \text{ and } R27,\ VR10$$

(d) VRS should have a total resistance of 10KΩ with the tolerance better than ±1%, and the resolution of each increment better than ±0.1% of the full scale. Since the total resistance shifts for 1000h loading time is specified, for convenience of manufacturing the VRS, as better than ±2% of the full scale, the value of the resistance should be checked at appropriate times.

3. Adjustment procedure (All symbols are referred to Fig. 3)

(1) Offset voltage of OA3

Set VR15 for the minimum output, and connect its wiper to earth, in order to ensure no voltage coming from OA2 (the minimum position of the wiper of VR7 is not necessarily zero ohm). After VR15 is turned to the maximum position, confirm that the triangular wave voltage observed at b is symmetrical against zero volt.

(2) Offset voltage of OA5

Connect v to earth, when SW1 is in position F(E) or F(N). Adjust VR9 for zero voltage measured at u.

(3) Setting of VR1 and VR2

VR1 controls the frequency of the triangular wave voltage, and VR2 controls its amplitude although this also affects the frequency. Therefore, set VR1 in the approximate middle point of its adjustable range, then adjust VR2 for approximately 5V pk-pk in amplitude measured at Pin 10 of OA2.

After this setting, VR1 is used for the frequency control, and VR7 is used for the amplitude control.

(4) Setting of VR8 in relation to VR1

VR8 controls the frequency of switching of the final output between c and d. This frequency can be changed in relation to the frequency of the triangular wave voltage which is controlled by VR1. Both the frequencies should be chosen so that the waveforms on a CRO are easy to watch. The changes of these frequencies, within the ranges, do not directly affect the measurements.

(5) Setting of VR5 and VR6

VR5 controls the DC-bias current of an opto-electronic coupler under test, and VR6 controls the sensitivity of an AC signal fed into the coupler, both through OA5.

Adjust VR5 to obtain 1.000V DC between test terminals T1-T2, when b is connected to earth.

Adjust VR6 to obtain 1.200V DC between T1-T2, when -2.500V DC is fed into b. Confirm the voltage between T1-T2 is 0.800V, when +2.500V is fed into b.

(6) Setting of VR3 and VR4

VR3 and VR4, with VRS control the relationships between the voltage b, e_b, and a standard voltage appearing at e, e_2, which is used for the calibration of the external force coefficient, K_F. The relationships are as follows:-

$$\frac{e_2}{e_b} \times 10 = \frac{\text{VRS(wiper)}}{\text{VR3 + R4 + VRS(max)}} \text{ at SW3 to tH}$$

$$\frac{e_2}{e_b} \times 1 = \frac{\text{VRS(wiper)}}{\text{VR4 + R5 + VRS(max)}} \text{ at SW to tL}$$

also

$$\frac{e_2}{e_b} = \frac{K_F}{h}\frac{i_f}{e_b} = \frac{K_F}{h}\frac{2\text{mV}}{4\text{mA}} = \frac{K_F}{h} \times 0.5 \ (\Omega)$$

The value of K_F is fixed for each model case. For example, if K_F = 625(ohm m) for h is in (m), adjust VR4 to achieve e_2 = 0.500V DC, when 1.000V DC is fed into b, and SW3 to tL (or × 1), and VRS dial is set to 1000 (9-9-10). Similarly, adjust VR3 to achieve e_2 = 5.000V DC at the same time conditions but SW to tH (or × 10). If the value of K_F exceeds the adjustable range of VR3 or VR4, R4 or R5 have to be changed.

(7) Setting of VR10, VR11, VR12, and VR13

These VRS are used in the calibration circuit of the Coriolis parameters of grid cards. VR12 and VR13 should be set first, and then VR10 and VR11 should be set. Although a triangular wave voltage can be used for the calibration of the calibration unit by feeding it in at b, the use of a DC voltage makes the calibration easier.

Adjust VR13 to achieve a voltage 1.000V DC at test terminal T3, when a DC current of 1.000mA is fed to b, VRS dial to 1000 or (99 + 10), and SW3 to vL (or × 1). Adjust VR14 to achieve a voltage 10.000V DC at T3, under the same conditions but SW3 to vH (or × 10).

Measure the resistance between V_H and earth, and between V_L and earth, respectively, when OA5 is operated, but v is open circuit (this can be realised by setting SW1 to F(N) or F(E) position).

Adjust VR10 so that the resistance measured between pL and earth is equal to the previously measured resistance between vL and earth. Also adjust VR11 so that the resistance between pL and earth is equal to the previously measured resistance between vL and earth. During these adjustments, OA3 should be operated with a zero input voltage, and p should be open circuit (this can be realised by setting SW1 to OS).

7. OPERATION

Before a grid card is calibrated by the grid-card calibrator, two inductors on the grid card should be calibrated by an inductor meter with an appropriate terminal selection for each inductor (see Fig. 9b).

The remaining calibrations are carried out by the grid-card calibrator:-

Preparation (see Fig. 7 and Fig. 9a)

1. Connect the calibrator to the power line.

2. Connect connectors CRO and SYNC (both on the rear panel of the calibrator) to the Y-input of a CRO and its synchronization terminal, respectively.

3. Connect a grid card to the 16-pin edge connector on the top of the calibrator.
   Connect lead wires J(W), J(N), Q(E), Q(N), Q(W), Q(S) of the grid card to the two sets of sockets on the top of the calibrator.
   Connect the two plugs of the calibrator to sockets T(N)-T(E) and T(W)-T(S) on the top of the calibrator.

Calibration (see Fig. 7 for the notations of controls)

P Set SW2 to the left side.
The CRO will display a pattern as shown in Fig. 10-2.
Adjust the control P (on the grid card) so that the pattern becomes as shown in Fig. 10-1.

OS Set SW2 to the right side, and leave it until the calibration has been completed.
Set SW1 to OS-N.
The CRO will display a pattern as shown in Fig. 10-2.
Adjust the control OS(N) (on the grid card) so that the pattern becomes as shown in Fig. 10-1.

Repeat the same procedure for OS(E), OS(S) and OS(W).

F Set SW1 to F-N.
Set VRS to a given number, with an appropriate setting of SW3 which gives the correct decimal point of the number.

The CRO will display a pattern as shown in Fig. 10-4 to Fig. 10-7.
Adjust control F(N) on the grid card so that the pattern becomes as shown in Fig. 10-3.

The pattern on the CRO can be adjusted to a convenient size by R15 (the front panel of the calibrator), without changing the ratio of the two voltage patterns.

If the pattern is as shown in Fig. 10-8, there is a fault in the grid card circuit.

Repeat the same procedure for F(E).

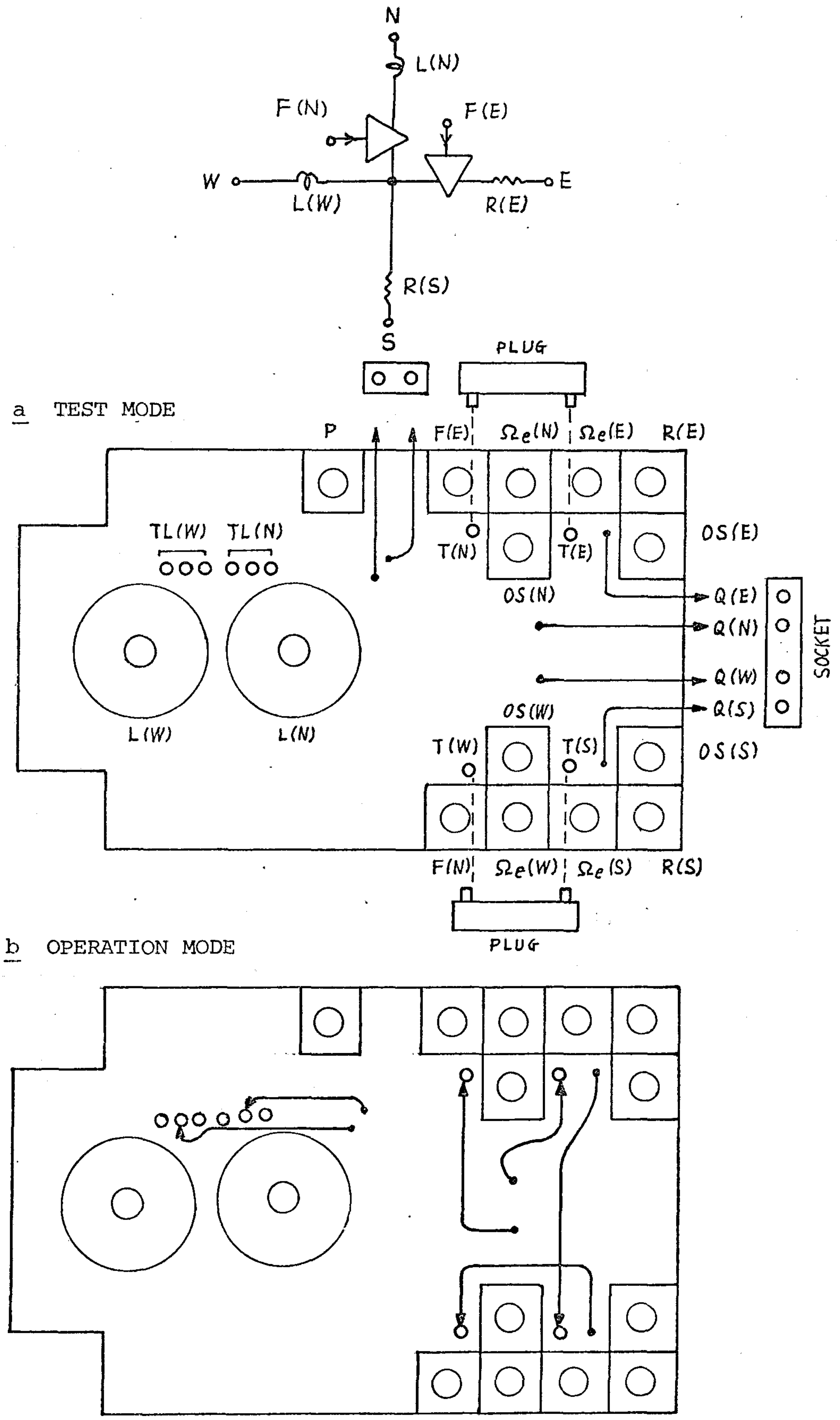


Fig. 9 Connection of terminals on a grid card.

		DC COMPONENT		AC COMPONENT
——	STANDARD VOLTAGE	E_1	+	e_1
---	VOLTAGE FROM CARD	E_2	+	e_2

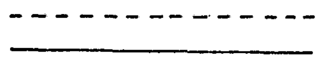
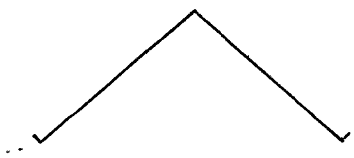
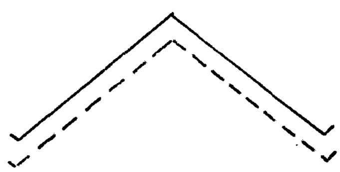
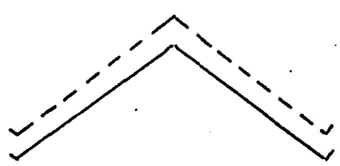
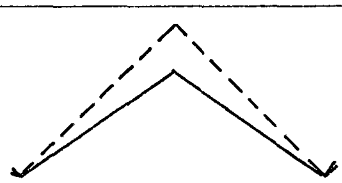
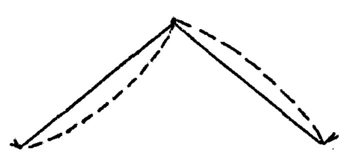
1		$E_1 = E_2 = 0$	$e_1 = e_2 = 0$
2		$E_1 \neq E_2$	$e_1 = e_2 = 0$
3		$E_1 = E_2$	$e_1 = e_2$
4		$E_1 > E_2$	$e_1 = e_2$
5		$E_1 < E_2$	$e_1 = e_2$
6		$E_1 = E_2 = 0$	$e_1 = e_2$
7		$E_1 < E_2$	$e_1 < e_2$
8		$E_1 = E_2 = 0$	$e_1 \neq e_2$ Non-linear

Fig. 10 Some output waveforms of the grid-card calibrator.
1 is ideal for P and OS. 3 is ideal for F, Ω_e and R.

<u>Ωe</u> Apply the same procedure as for <u>F</u>, but SW1 should be set to Ωe-N, Ωe-E, Ωe-S, Ωe-W, and controls Ωe(N), Ωe(E), Ωe(S), Ωe(W) should be adjusted, respectively.

<u>R</u> Connect an appropriate 'Adjacent grid card' to Socket <u>A</u> (on the side of the calibrator).
Set SW1 to R-E.
Set VRS to a given number, with an appropriate setting of SW3 which gives the correct decimal point of the number.

The CRO will display a pattern as shown in Fig. 10-4 to Fig. 10-7.

Adjust control R(E) of the grid card (on the top of the calibrator) so that the pattern becomes as shown in Fig. 10-1.

R15 can be used in the same way as in <u>F</u>.

Repeat the same procedure for R(S), with another 'Adjacent grid card'.

<u>Completion</u> (see Fig. 9b)

The calibration is now completed. Disconnect all the connections between the grid card and the calibrator, and also disconnect the grid card from the edge connector of the calibrator.

Connect the lead wires on the grid card to its sockets as shown in Fig. 9b.

8. CONCLUSION

An apparatus for setting the time-independent variables of the tide/surge equations to each grid card has been developed. This was used successfully for setting all the grids of a model of the sea around the British Isles.

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REFERENCE

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