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Wave Monitor Manual

Issue	Date	Revision
7	08/05/09	1 change address to Crowthorne

CE

This product is certified to comply with all relevant EU directives

As part of our policy of continuous improvement we would welcome any suggestions for changes to the document.

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CONTENTS

1 SAFETY

The equipment has been designed to be compliant with EN60950.

The earth conductor for the equipment is the protective earth for the equipment. The conductor is connected to the module case. All module panels are earthed via an extended pin on the module connectors.

Only the mains cable supplied with the equipment should be used to make connection to the A.C. mains supply. The mains socket must incorporate an earth connection. If it is necessary to change the plug style on the supplied lead the replacement plug should be terminated as follows:-

L	Live	Brown wire
N	Neutral	Blue wire
E	Earth	Green/Yellow wire

The IEC connector on the rear of the case frame incorporates a 20mm mains fuse rated at 2 amps 'F'.

****** IMPORTANT ******

The power supply module supplied with this equipment is intended for operation on an A.C. mains supply 120V or 240V, 50-60Hz.

2 GENERAL DESCRIPTION

The instrument is a simple robust device for the measurement and recording of water waves in hydraulic models and ship tanks. It works on the principle of measuring the electrical conductance between two parallel wires configured as a probe. The reference signal used to measure the conductance is an AC waveform to avoid electrolysis at the wire surfaces.

2.1 Probes

The standard form of probe supplied consists of a pair of stainless steel wires, 1.5mm in diameter and spaced 12.5mm apart. However the flexibility of the drive and sensing circuits enables a very wide variety of probe configurations to be employed. This versatility enables the user to construct probes to suit his own requirements, of which the following are a few examples.

Flat ribbon probes for high speed towing in ship tanks.

Long wires carried on either side of a support structure.

Specially shaped probes attached to the side of ship models for the measurement of pitch, heave etc.

2.2 Wave Monitor Module

Each Wave Monitor Module generates an AC waveform which energises the probe and a detector to measure its electrical conductance. It also contains correction processing to compensate for the resistance of the wire used to connect it to the probe.

Each Wave Monitor Module provides three output signals – a voltage output, a current output and a galvanometer output. The user can connect to whichever of these is relevant to his monitoring system.

There are manual adjustments on the front of each module to set the datum offset and the sensitivity. There is also a preset adjustment to compensate for wire resistance.

2.3 Mechanical Construction

The Wave Monitor Modules are mounted in a card frame that also houses a mains power supply. Various card frames are available, depending on the number of modules required.

The probes have to be mounted vertically above the water, such that approximately 50% of their length is immersed when the water is calm. To calibrate the system the user has to be able to adjust the level of immersion. A special probe calibration holder is available which has refernce pegs at defined spacing to allow the depth of immersion to be accurately adjusted.

3 SETTING UP PROCEDURE

3.1 Connections

3.1.1 Mains Power Supply

The mains supply to the unit is via a 3-pin IEC socket on the rear panel. A 2 metre lead terminated in a UK 13A plug is provided with each system.

Units are shipped configured for operation from a nominal 230VAC supply. If it is to be operated from a 120VAC supply then before connecting power the user should release the two captive retaining screws on the fron of the power supply, remove it and change the power selector switch on the PCB from 240V to 120V.

3.1.2 Probe Connection

The connection to the probe is via two red 4mm sockets on the front of each Wave Monitor Module. For convenience these are also available on the rear panel. The two terminals should be linked to the two terminals on the probe using two core wire. There is no requirement for the wire to be double-insulated, or for it to be twisted, but it should be rebust enough to withstand whatever handling it may be subjected to in normal use.

The probe ends of the wires should be terminated in 4mm plugs. These will fit directly into the probe calibration holder (if used). If probe calibration holders are not used then back-back 4mm socket adaptors should be used to interface to the 4mm plugs incorporated in the probe. These adaptor are simply metal tubes with insulating sleeves.

3.1.3 Output Connections

Output connections, along with the alternative probe connections, are made via terminal blocks on the rear panel. The connections are shown in Fig. 1 and summarised as follows:-

1. Voltage output (maximum ±10V).
2. Current output (maximum ±10mA) from a source impedance of 1KΩ.
3. Galvanometer output (maximum ±0.05mA) with a parallel resistance of 240 ohms.
4. Twin wire probe input.
5. Twin wire probe input.
7. Common (outputs only).

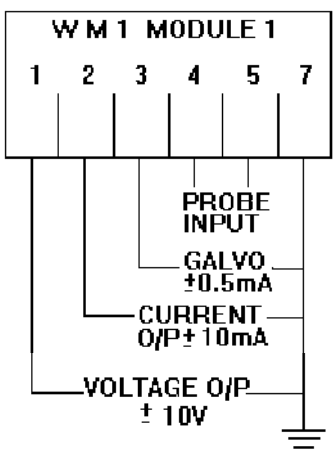


Fig. 1 Terminal Block Connections

The unit is supplied with the common line connected to chassis and to mains earth. If it is required to operate with the output signal isolated from earth it is necessary to remove the earth link between the white and green/yellow wires on the extreme left-hand module socket when viewed from the rear with the rear cover removed. In this case it is essential to connect the output signal via the rear terminal block.

3.2 Calibration

3.2.1 Frequency Selection

When probes are used in close proximity to each there is a risk that the signal used to energise one may influence the reading on another. To overcome this probes in close proximity should be energised at different frequencies. To set the frequency the Wave Monitor Module should be removed from the chassis (by releasing the two screws at the bottom of the front panel) then withdrawn from the front. There is a selctor link on the PCB allowing the choice of six different frequencies.

3.2.2 Sensitivity

The small jumper mounted in the circuit board alters the amplitude of the energisation voltage which is applied to the SET DATUM control. For probes up to 500mm in length the jumper should be set to position "S", i.e. with its jumper moved towards the front panel. For longer probes the jumper should be set to position "L", i.e. towards the rear plug connector to reduce the sensitivity of the SET DATUM control.

3.2.3 Lead Compensation

If there is significant electrical resistance in the wire used to connect the probe to the Wave Monitor Module the linearity of the output may be degraded. To overcome this Wave Monitor Module includes provision to compensate for the resistance. This adjustment only needs to be carried out once (unless the wire is changed):

Disconnect the wire cable at the probe end and insert the plugs into the blue TEST sockets on the front panel. Turn the SET OUTPUT control to its fully clockwise position (i.e. maximum), then set the toggle switch to the TEST position. Adjust the SET DATUM control until the pointer of the balance meter is in its central position. Press the Datum push button and rotate the COMP control with a screwdriver to restore the balance meter is in its central position. Correct compensation is achieved when pressing and releasing the push-button results in no change in the position of the meter pointer. The plugs can then be removed from the TEST sockets and reconnected to the probe.

When this adjustment is completed the toggle switch should be returned to the OPERATE position.

3.2.4 Set Datum

The Wave Monitor Module provides an output that is proportional to the depth of immersion of the relevant probe, and ideally reads zero in the quiescent state (i.e. in calm water). The probe should be fixed such that it is approximately 50% immersed in water when there are no waves.

After setting the probe appropriated, adjust the SET DATUM knob to give a reading of zero on the external monitoring system and/or the meter built into the module.

It may be necessary to re-calibrate the datum if the water level changes or the salinity changes. It may also be affected by the temperature of the water.

Note that this adjustment can only be made when the toggle switch is in the OPERATE position.

3.2.5 Set Output

The reading of prime importance to the user is the actual water level at any given time relative to the datum reference. The outputs are proportional to the depth of immersion, but the system gain must be adjusted to give the required sensitivity (e.g. 0.1V/mm).

To adjust the sensitivity, first set the datum as described above, then move the probe so that it is immersed to the level corresponding to the highest reading required (e.g. drop it 100mm lower than the datum level). The SET OUTPUT knob should then be adjusted to give the required output (e.g. +10V to calibrate to 0.1V/mm). The lever adjacent to the knob can be used to lock it in position.

If the lead compensation has been adjusted correctly then lifting the probe above the water datum by the same amount (i.e. 100mm in this example) will give the same amplitude reading but in the opposite polarity.

It may be necessary to re-calibrate the sensitivity the salinity or water temperature changes.

Note that this adjustment can only be made when the toggle switch is in the OPERATE position.

3.2.6 Calibration and Datum Check

Before taking any meaningful measurements it is recommended that the datum and sensitivity are checked by raising and lowering the probe in calm water and noting the change in the output reading. This operation is facilitated by means of the calibrated holder which has a series of holes drilled along its length accurately spaced at 10mm. The probe can be raised and lowered by a multiple of 10mm by using the pin provided as a stop. Once the calibration has been set and established the only further adjustment needed may be to trim the SET DATUM.

4 USE AND CARE OF THE PROBES

The instrument calibration is not markedly effected by distortion of the probe. No great accuracy is required in the wire spacing and provided the instrument is set up as described in the previous section, it is only necessary to ensure that gross distortion of the probe is avoided.

This type of probe is fairly insensitive to the electrical effect of deposits on the wires, but large accumulations of material affect the flow of water around them and should be removed. This can be done either by rubbing with very fine emery cloth or by dipping the probe wires into 2N hydrochloric acid, taking care that the acid is not allowed to come into contact with the electrical connectors.

Films of oil or grease on the wires have a serious detrimental effect and must be thoroughly removed. The probes should not be used in water having a film of oil on the surface.

The conductivity of the water changes with temperature (2% per deg.C approx.) and it is also dependent on the concentration of dissolved salts in the hydraulic model. In a new model, especially one moulded in cement mortar, the dissolved salt concentration can be very variable, both with time and with position in the model. It is therefore advisable to run waves in a new model for a few days before attempting to make any measurements. Regular checks on the probe calibration during this time will indicate when the dissolved salt content of the water is steady and uniform. This is particularly necessary if very long wave probes are to be used, because changes of salinity along the length of the probe will result in poor performance. Generally calibration checks need to be made twice daily, but probe calibration is a simple operation, being a single adjustment in still water because the probe has a linear response (see Section 3).

5 OPERATING ENVIRONMENT

Operating temperature range: 0 - 50°C.

Humidity: 95% non-condensing.

Mains Voltage: 240V or 120V (+6%, -10%), 50-60Hz.

The signal conditioning circuitry in the wave monitor module incorporates sensitive electronic circuitry. High electro-magnetic fields, such as those created by portable telephones, should be avoided when taking measurements. The highest frequency used in the circuit is 10kHz consequently there will be no unacceptable emissions from the equipment.

The IEC mains connector incorporates an RFI filter to provide protection against mains-borne interference which may affect calibration or measurements.

6 CIRCUIT DETAILS

6.1 Power Supply Module

The unit consists of 2 identical 15 Volt regulator circuits connected in series. The mains transformer has 2 tapped primary windings connected in series or parallel depending on the voltage supply. The secondary windings provide a nominal 18.8 volts r.m.s. which is rectified by the rectifiers REC 1 and REC 2. The unregulated D.C. voltage applied to the smoothing capacitors C1 and C2 should lie between the limits of 17 volts minimum and 30 volts maximum, if the mains voltage connections have been correctly selected. The regulators have internal fold back overload, thermal and short circuit protection and have a short circuit current of 230 mA.

The output voltage is not adjustable and should be 15V $\pm$ 0.6V.

6.2 Wave Monitor Module

The alternating voltage to drive the probe is produced by a square wave oscillator comprising the operational amplifier IC8. This produces a stable amplitude of 12 volts peak to peak determined by the zener diodes ZD1 and ZD2. The frequency is set by selecting one of the resistors R16 to R21 by means of the plug and socket arrangement on the circuit card. The range of frequencies covered is 5 KHz to 10 KHz in approximately 1 KHz steps. The oscillator output amplitude is controlled by the SET DATUM potentiometer VR2, for long probes (over 500mm) the conductivity of the probe is low, and requires a small drive voltage from the oscillator. In order to reduce the sensitivity of the setting of VR2, R15 is introduced in series with it by opening the switch S1.

The circuit diagram of one of the two probe drive amplifiers is shown separately in Fig. 2. In this simplified form it is easier to see how the amplifier operates. In the following description it is assumed that no common mode signals are present and that the two input amplifiers act as a balanced pair.

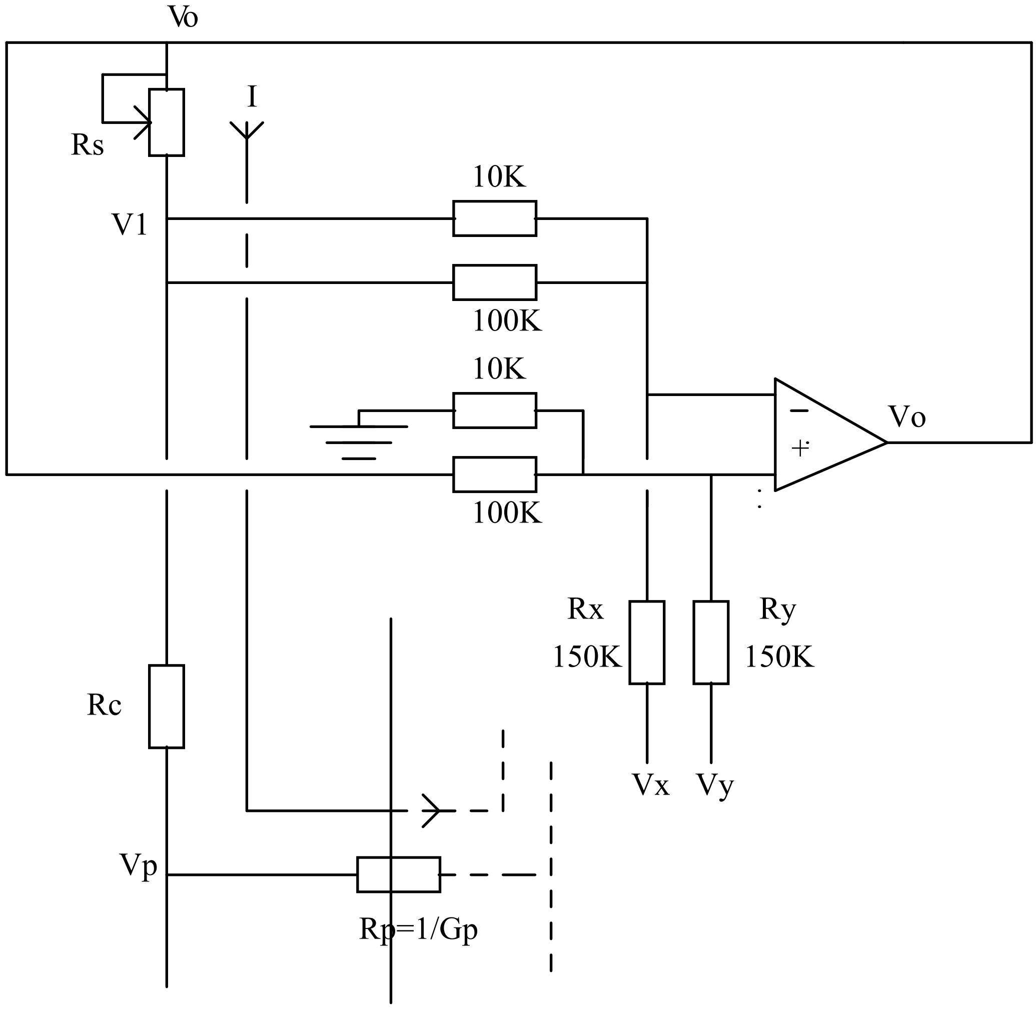


Fig 2. Probe Drive Amplifier

In the simplified diagram, Vp is the voltage which appears on one of the twin wires. Rc is the series combination of the probe electronic cable and the 10Ω measuring resistor in the electronics unit, and Rs is the series combination of the 100Ω resistor and the 100Ω variable resistor in the amplifier output lead. Vo is the amplifier output voltage. Vx and Vy are input terminals for oscillator signals.. Amplifier IC1 has the oscillator signal applied to Vx, with Vy grounded, and amplifier IC2 has the oscillator signal applied to Vy with Vx grounded.

The purpose of the amplifier is to produce the equivalent of a very low impedance voltage source Vp at the probe wire. The obvious way to do this is to feedback the voltage Vp (through a suitable resistor) to the inverting input of the amplifier. This cannot easily be done, however, because Vp appears at the probe wire, which may be up to 100 metres from the electronic unit.

The equivalent to feeding back Vp is to feedback a combination of Vo and V1, which can both be measured in the electronic unit. Because Rs and Rc are much smaller than the other resistors in the circuit, the current I can be considered to be common to them both. (The small error introduced by this assumption can be removed by a suitable procedure for adjusting Rs).

It can readily be seen that:

$$V_P = V_1 - Ir_C \qquad (1)$$

and also that:

$$V_O - V_1 = IR_S$$

$$\therefore\ I = \frac{1}{R_s}\{V_0 - V_1\} \qquad (2)$$

substituting (2) for I in (1):

$$V_P = V_1 - \frac{R_c}{R_s}\{V_O - V_1\}$$

$$\therefore\ V_P = V_1 \{ 1 + \frac{R_c}{R_s} - V_O \{\frac{R_c}{R_s}\}$$

In the actual circuit, Rs is adjusted to be equal to 10Rc. Then:

$$V_P = 1.1\ V_1 - 0.1\ V_O$$

V1 is fed back to the inverting input and Vo to the non-inverting input through resistors selected to give the required weightings of 1.1 and 0.1.

The input resistors Rx and Ry are selected so that

$$V_P = -\frac{1}{15}\text{ V (amplifier ICI) or V} = +\frac{1}{15}\text{ V (amplifier IC2).}$$

The differential voltage applied to the twin wires by the combination of IC1 and IC2 is therefore equal to $\frac{2}{15}V_{osc.}$ The maximum current which the amplifiers can supply is 2mA.

The current in each probe wire is detected by measuring the voltage drop across the 10 ohm series resistors R23 and R24. For each resistor, the voltage drop must be measured with a differential amplifier with an input resistance high compared with 10 ohms.

It is then also necessary to detect the difference between the 2 voltage drops in order to reject common mode signals.

In the circuit diagram, the amplifier circuit IC3 performs both of these functions. Its gain is such that approximately 1 volt p-p output signal is produced when the maximum probe current of +2 mA flows in each probe wire.

For correct operation of this circuit the 4 resistors R26, R28, R29 and R30 are matched to 0.1%. The effect of a mis-match would be to produce an output voltage when the probe is out of the water. Although this voltage would be small, it causes problems in the method used to restore calibration after changes of water conductivity.

For normal operation the switch S2a is in the OPERATE position, and the signal feeds forwards through C6 to the precision rectifier IC5 and IC6. The signal appearing at the junction of D2 and R45 is a half wave rectified version of the signal and this is converted into a full wave rectified signal of half amplitude by feeding the unrectified signal forward through the resistors R40 and R41. Exact balancing of the two halves of the full wave signal is achieved by adjusting the BALANCE potentiometer VR3. This ensures that the ripple conent of the final D.C. output signal is at a minimum.

IC6 is an inverting amplifier with smoothing provided by C7. The time constant of C7-R47 gives an output falling to 95% at 10 Hz.

IC7 is an inverting amplifier of which the gain can be varied by the SET OUTPUT control VR4. An offset derived from the power rail via R50 and VR5 makes the output zero when the probe current is 1 mA (peak). VR5 is adjusted to set the output at -10 volts with the probe disconnected and with VR4 set to its maximum.

A small signal of approximately 10% of full scale can be injected via R55 by means of the push button contacts PB1/2. This enables the corresponding recorder trace to be identified.

The output is taken to the output socket and back connector of the module, also to a centre zero balance indicator on the front panel. The indicator has a full scale range of about $\pm$ 1 volt and limiting diodes are fitted to prevent it being damaged by larger signals.

Variation of the oscillator output voltage is the method used to adjust the range of the wave probe. The correct energisation is that which causes a current of 2 mA to flow round the probe circuit when the probe is immersed to the full scale of the required range.

As the calibration of the instrument is linear, and goes through zero probes current at zero immersion, the probe current will be 1 mA when it is immersed to half of the full scale depth. The offset circuit in the precision rectifier makes the instrument output voltage go to zero under these conditions.

The method of setting the range is therefore to immerse the probe in still water to a depth of slightly more than half of the p-p maximum expected wave height. With the probe set in this position the energisation is adjusted using the SET DATUM potentiometer until the balance indicator goes to zero.

Full scale of the range is then slightly more than the expected p-p amplitude of the largest wave.

Changes of water conductivity will change the slope of the calibration line, so that the current at the original static immersion depth will differ from the 1 mA originally set. The method of restoring the calibration is therefore as follows:-

a) Return to the original depth of probe immersion in still water, (i.e. stop the waves).

b) If the conductivity of the water has changed since the datum was set, the balance indicator will have moved away from zero.

c) If this is the case, the SET DATUM potentiometer is adjusted to bring the indicator back to zero. The calibration is then restored to its original value.

As has already been described, the method used for compensating for cable resistance involves making Rs (Fig. 3) equal to 10Rc where Rc includes the cable resistance.

Because of the finite currents flowing in the amplifier input resistors, the compensation provided by doing this is not quite exact. It is also impractical to compensate by a method which involves measuring Rc and then setting Rs to an appropriate value.

A test circuit has therefore been incorporated in the electronic module to facilitate this compensation. This comprises the amplifier IC4 which is brought into operation by depressing the switch S2a into the TEST position, at the same time the zero offset of the precision rectifier is increased via R46 by the operation of switch S2b.

The test procedure is to unplug the probe connecting cable at the probe end and to plug it into the TEST sockets on the front panel instead of the connector at the top of the twin wire.

The 1K ohm resistor R34 (in parallel with the input impedance of IC4) acts as a dummy twin wire probe. Pressing the push button PB1 shunts the 1K ohm resistor with a 56 ohm resistor, and thereby changes the resistance of the dummy probe.

The amplifier IC4 is balanced, so that connection to it does not unbalance the wave probe input amplifier IC3. The output of IC4 feeds through the precision rectifier to the balance indicator as before.

The amplification through the test circuit is dependent on the setting of the SET OUTPUT control VR5 and this should always be set to maximum when adjusting the compensation. The balance indicator then nulls when the input voltage to the dummy probe is approximately 100 millivolts.

This input voltage corresponds to Vp in Fig. 2. Having connected the probe lead to the TEST input the SET DATUM potentiometer is adjusted until the water nulls.

The push button switch is then depressed to change the resistance of the dummy probe, and the compensating resistors VR1a and b adjusted until the balance indicator nulls again.

This ensures that Vp remains constant when the probe resistance changes, and therefore makes the effective source resistance of Vp equal to zero.

The lead is then removed from the test input and reconnected to the probe. The datum setting is then carried out as already described.

7 COMPONENTS LIST

7.1 Wave Monitor Module

Resistors:- All 2% metal film, Mullard MR25 or equivalent, unless otherwise stated.

Circuit Reference	Value	Circuit Reference	Value	Circuit Reference	Value
R1	10K	R21	100K	R41	2K2
R2	100K	R22	2K2	R42	10K
R3	100R	R23	10R	R43	10K
R4	100K	R24	10R	R44	2K2
R5	10K	R25	10R	R45	2K2
R6	150K	R26	4K7*	R46	100K
R7	150K	R27	10R	R47	22K
R8	10K	R28	4K7*	R48	2K2
R9	100K	R29	4K7*	R49	2K0
R10	100R	R30	4K7*	R50	22K
R11	100K	R31	120K	R51	1K
R12	10K	R32	120K	R52	10K
R13	150K	R33	56R	R53	3K9
R14	150K	R34	1K	R54	1K
R15	100K	R35	4K7	R55	220K
R16	39K	R36	47K	R56	200K
R17	47K	R37	4K7	R57	240R
R18	56K	R38	47K	R58	100K
R19	68K	R39	10K	R59	100K
R20	82K	R40	2K2		

* Matched to ± 0.02%

Capacitors

Circuit Reference	Value	Type	Tolerance (%)	Voltage
C1	220 pf	Polystyrene	10	160V
C2	220 pf	Polystyrene	10	160V
C3	0.1 uf	Polyester	20	100V
C4	1000 pf	Polystyrene	2	160V
C5	1000 pf	Polystyrene	2	160V
C6	1.0 uf	Polyester	20	250V
C7	0.22	Polyester	20	100V

Semi-Conductors

CIRCUIT REFERENCE	Type
IC1 - IC7	741TC
IC8	CA314OE
D1-D4	IN4148
ZD1, ZD2	BZY88C 5V6

Potentiometers

Circuit Reference	Value	Type
VR1	100R	81A2A-B28 A05/A05
VR2	20K	3540S-1-203 (10T, w.w.)
VR3	500R	72P (Cermet)
VR4	20K	3540S-1-203 (10T w.w.)
VR5	10K	72P (Cermet)

Misc.

M1	Level meter model Sv5
PB1	Level meter push button switch 2 No 8225A
S2	Miniature toggle DPDT 7201A
SK1-SK4,	4mm round sockets
SK5	"bnc" socket round and plug
	10 Turn dial H 507-6
	32-way plug

7.2 Power Supply Module

Resistors:- **All 2% metal film, Mullard MR25 or equivalent, unless otherwise stated.**

Circuit Reference	**Value**
R1	4.7K
R2	4.7K

Capacitors

Circuit Reference	**Value**	**Type**	**Tolerance (%)**	**Voltage**
C1	1000 uf	Electrolytic	-25, +100	63
C2	1000 uf	Electrolytic	-25, + 100	63
C3	0.22	Polyester	20	250V
C4	0.22	Polyester	20	250V
C5	0.47	Polyester	20	250V
C6	0.47	Polyester	20	250V

Semi-Conductors

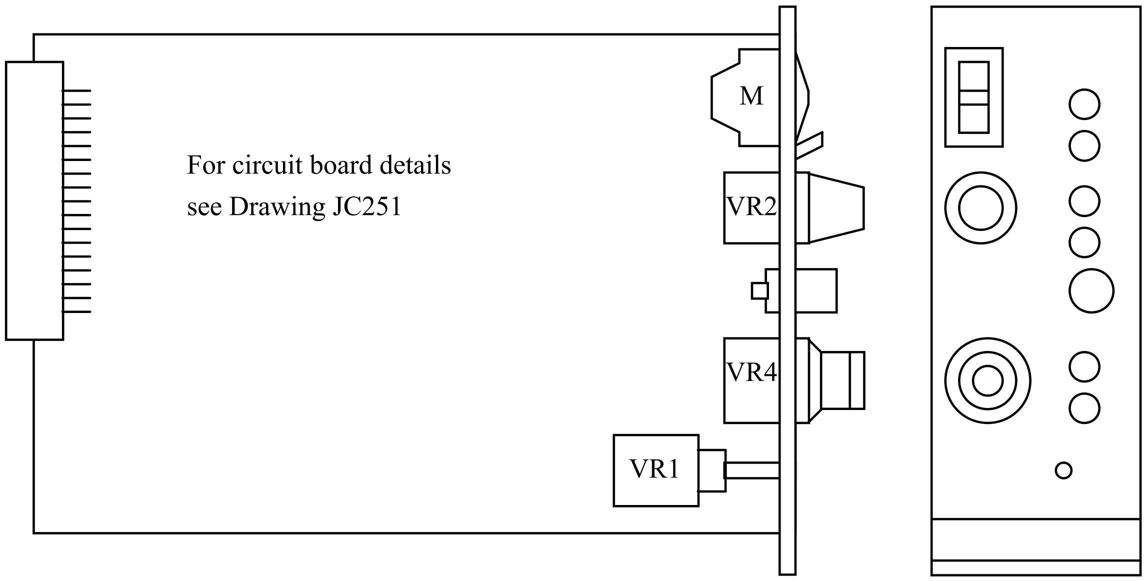
Circuit Reference	**Type**
Recl	W01
Rec2	W01
Reg1	7815
Reg2	7815

Transformer

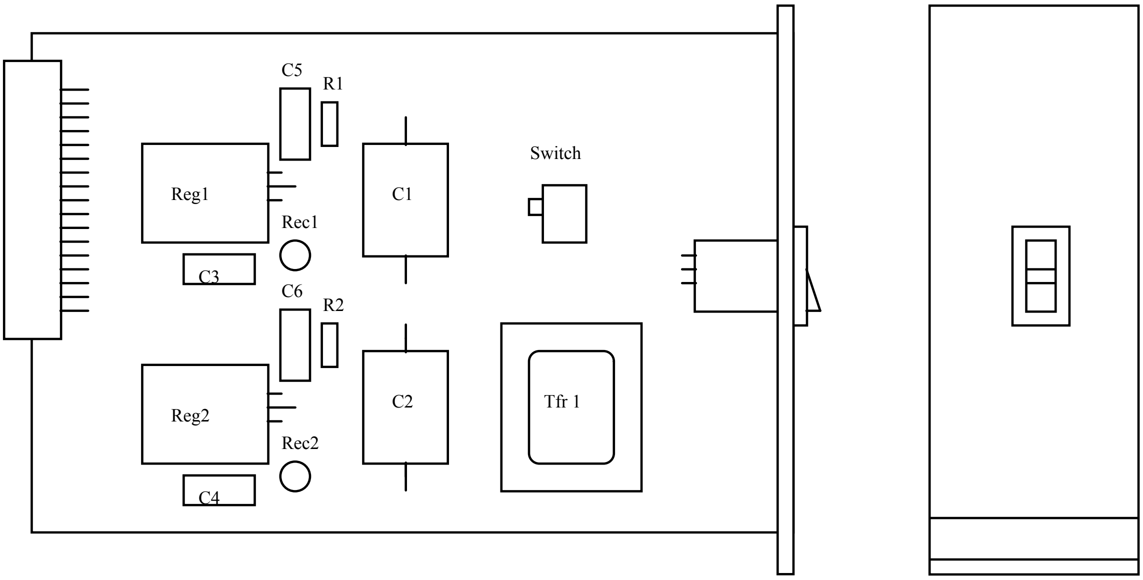
Circuit Reference	**Type**	**Voltage**
TFR1	ED1540	18.8

Misc.

S1	Illuminated Miniature toggle switch DPDT 10-Way plug

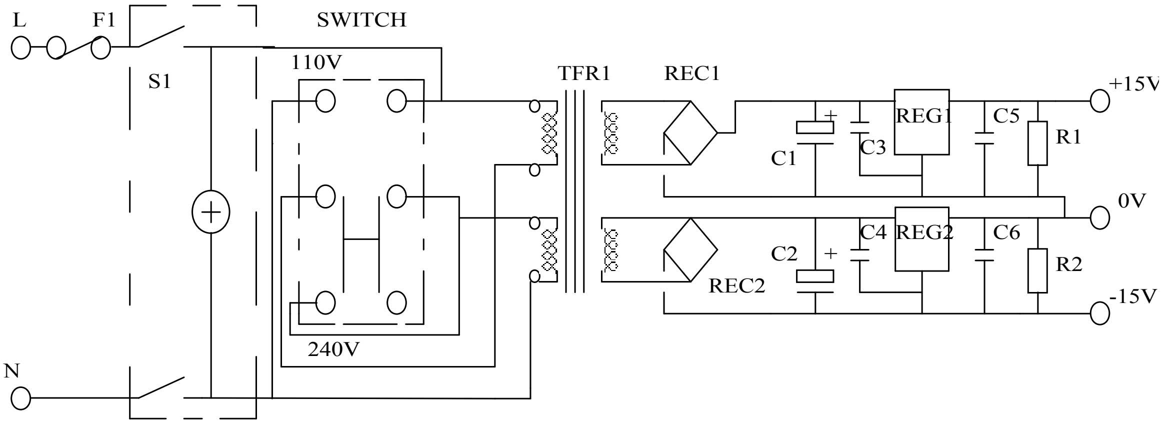


WAVE MONITOR MODULE
General Assembly



WAVE MONITOR POWER SUPPLY MODULE

General Assembly



WAVE MONITOR POWER SUPPLY CIRCUIT DIAGRAM

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