I.O.S.

THE IOS ACOUSTIC COMMAND AND MONITORING SYSTEM

Part 2 - The Shipborne System Mark III

G. R. J. PHILLIPS.

Report No 96/2
1980

NATURAL ENVIRONMENT RESEARCH COUNCIL
INSTITUTE OF OCEANOGRAPHIC SCIENCES

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Foreword

The system has been developed as a service for U.K. oceanographic science to provide medium range (10 km maximum) remote control and real time monitoring of a wide variety of oceanic sampling equipment. It divides naturally into several categories which have been described in separate reports (some detailed to handbook level). These instruments have been developed to their present level over a number of years and may be subject to further revision and expansion. As and when these are significant reports will be updated or extended. Many of the instruments have been designed to accommodate the addition of facilities. These facilities must only be added by an engineer fully conversant with the system.

Part One - Operating Principles and Practices.

Part Two - Shipborne System Mark III.

Future parts will cover

The Command Release 200 Series and Acoustic Beacon Type H,

A Lightweight Portable Facsimile Recorder,

Remote Monitoring Systems,

Transponders,

Sea Unit Hardware and some of its problems,

and the

Shipborne System Mark IV.

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THE IOS ACOUSTIC COMMAND AND MONITORING SYSTEM

Part II

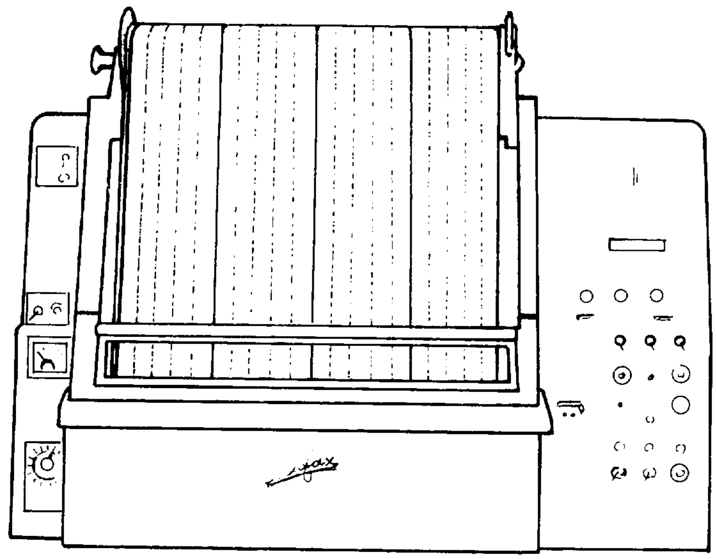
The Shipborne System Mark III

G.R.J. Phillips B.Sc.

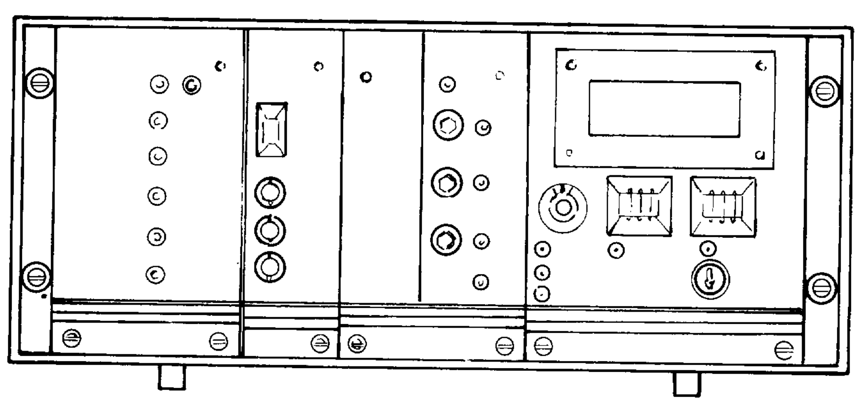
Summary

The IOS Acoustic Command and Monitoring System Shipborne System Mark III is described at a variety of levels. The general principles have been described in IOS Report 96, Part One. First the overall design is reviewed and then the component parts are described to handbook detail, in the light of practical applications. The system divides naturally to three sections, Shipborne Acoustic Transducers, Recording and Display, and the Deck Control Unit Mark III. A supplementary package containing additional handbook material is supplied to users of the system.

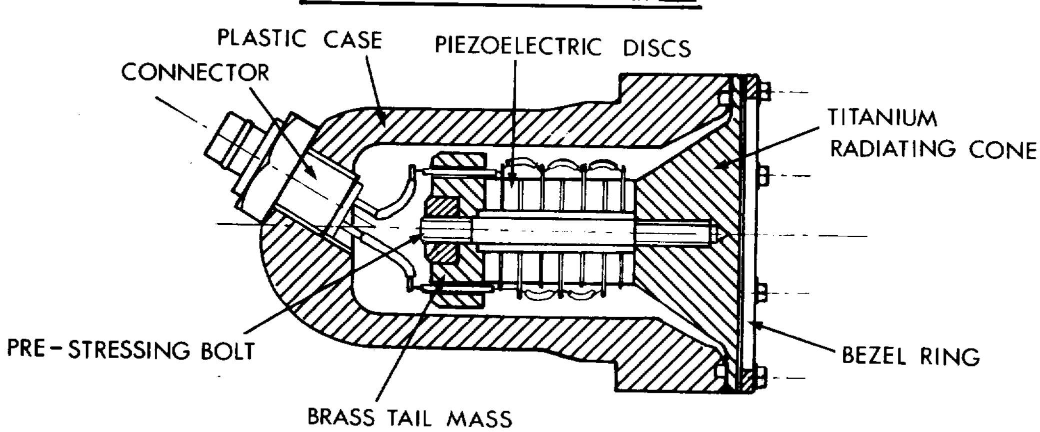
FIG. 1 THE COMPONENTS OF THE SHIPBORNE SYSTEM Mk III



I.O.S. Mk III PRECISION ECHO SOUNDER



DECK CONTROL UNIT Mk III



Mk III T TRANSDUCER ELEMENT

THE SHIPBORNE SYSTEM MARK III

1. Introduction

1.1 Overall Design

The Mark III system (Fig. 1) was designed to coordinate the Precision Echosounder Mark III System (PES), the CR200 Series releases, the Acoustic Beacon type H, and the Net Monitor type J into a complete medium range, deep ocean, monitoring and control system. The Mark III deck control unit was therefore designed to interface with an individual PES type transducer used as a transceiver and provide all the necessary drive signals required by the PES recorder; these form the Shipborne System Mark III.

1.2 Operation

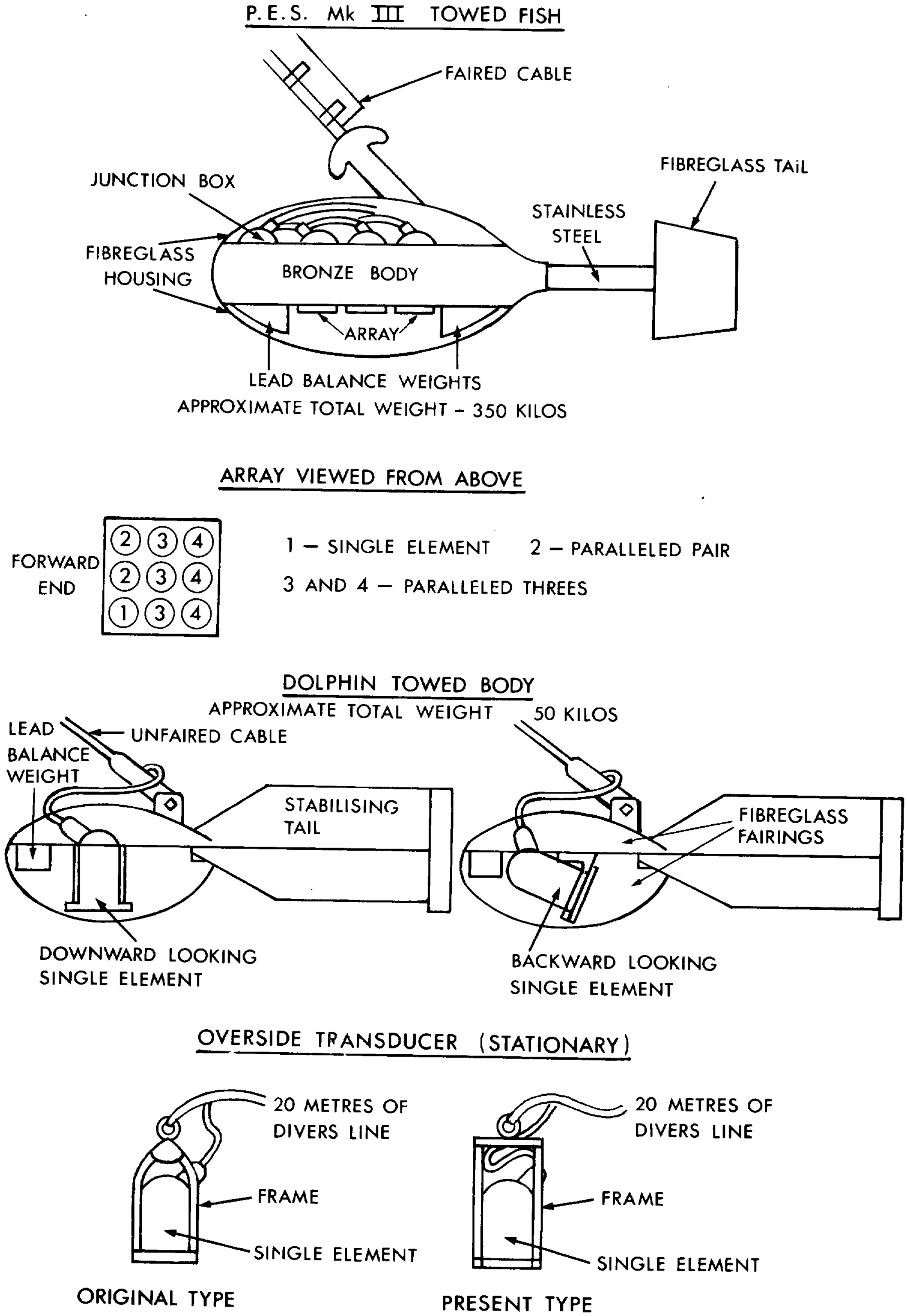
The standard deep ocean system uses a PES transducer mounted in, but electrically disconnected from the echosounder fish array. This is then electrically connected to the Transducer Input at the rear of the Deck Control Unit (DCU); the DCU Receiver Output on this panel is connected to the Auxiliary Input on the back of the recorder; the Sweep Drive from the DCU rear panel is connected to the External Input on the front of the recorder, the switch is moved from Internal one kilohertz to External and the system is ready to run. None of these connections has a significant effect on the ability of the PES to operate normally to 5000 m but the sweep drive will alter the scale displayed unless Period on the DCU is set to 100.

Since this original design was produced in 1975 a variety of other combinations have been successfully used. The basic requirements of the shipborne system are: to generate command signals suitable for transmission; to process received signals; and to record and display them.

2. Shipborne Acoustic Transducers

The Mark III system was designed to use exclusively the PES Mk III transducer single element. This exists in two forms, one in an aluminium housing and the more recent version in a titanium and Nylotron housing to reduce corrosion. The transducers have a bandwidth of 2.2 kilohertz centred on 10.2 kilohertz, a Q of 4.5. They will handle 40 watts of acoustic power at the surface and 60 watts at the normal operating depth of 5 to 10 metres. Their efficiency is about 90%. Their sensitivity is roughly uniform over a cone of base angle 90^{o} symmetrically distributed about the perpendicular to the end face and falls off rapidly outside this zone.

FIG. 2 TRANSDUCER CONFIGURATIONS



The basic design is a scaling of the unit developed for the I.O.S. Gloria system which operates at 7 kHz. The main improvements on previous designs were removal of the severe losses caused by the rolling 'O' ring seal of the moving piston and freedom from the restrictions imposed by nodal support.

Transducer Configurations

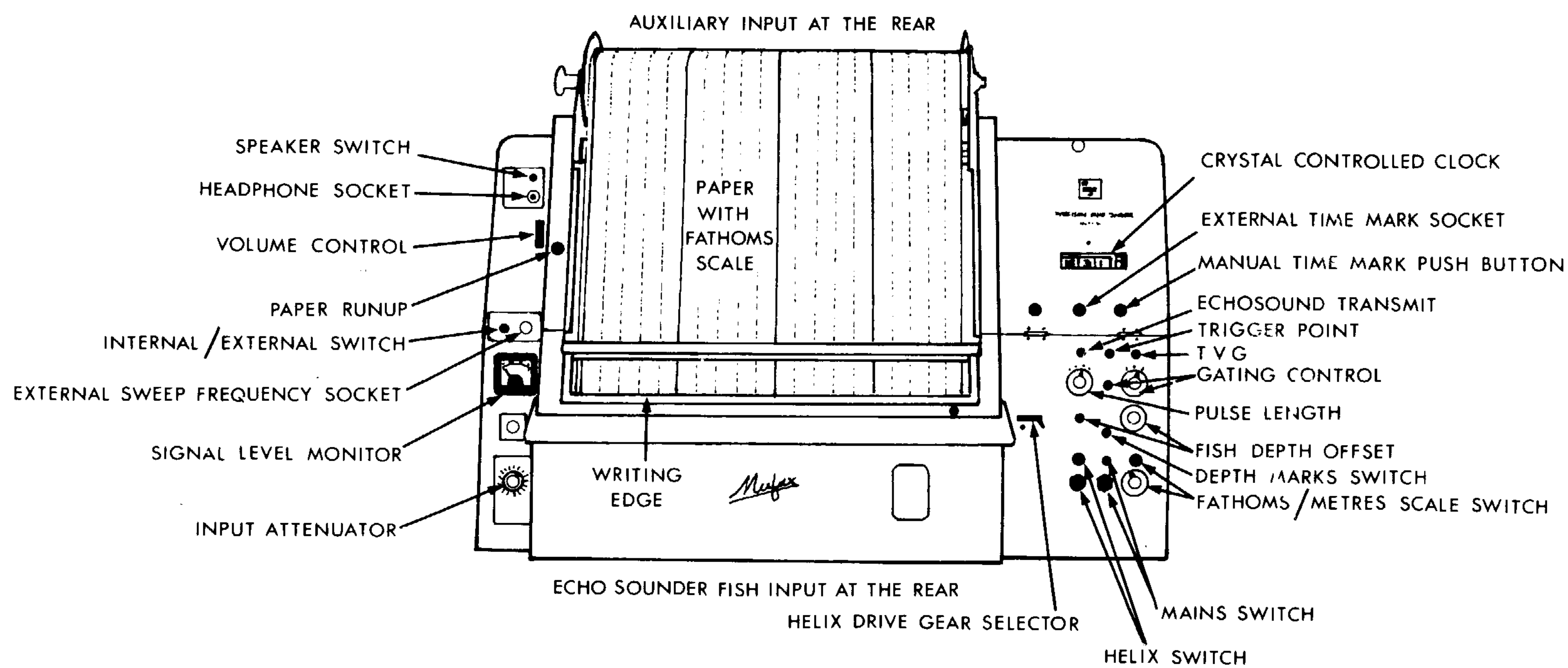
The normal mounting is as part of the PES Mk III towed fish (Fig. 2) or hull transducer array: mountings and cables are available to deploy an individual transducer when stationery or moving at very slow speed - the overside transducer (Fig. 2); a towable 'Tadpole' was developed to take an individual transducer; this used a heavy brass casting and faired armoured cable to keep it deep in the water and a stainless steel tail for stability; it is now very expensive: a less expensive recent innovation is the 'Dolphin' towed body (Fig. 2) which uses a fibreglass faired body and a large aluminium tail combined with a rough unfaired towing cable to maintain depth: both tadpole and dolphin are towable to six knots. All these mountings are basically downward looking and therefore of limited use at depths shallower than 500 metres. Tadpole and dolphin vehicles have both been modified to accept transducers inclined to face at a backward looking angle. This greatly improves the operation of towed systems such as nets and dredges.

The physical siting of the transducer in relation to normal ship's functions can be critical. Features such as bow thrusters, main propellers, ship's wake, bow waves and engine room pumps can all cause loss of signal through aeration and noise generation.

3. Display and Recording

The system being designed around the PES Mk III uses that recorder for display and recording. However, other facsimile recorders have been used and are briefly described. Alternative display and recording techniques have been used and some are discussed in the report on the Mark IV system.

The Mark III recorder (Fig. 3) is a converted 'Weather' facsimile recorder produced by Muirheads under the trade name Mufax. It operates by varying the current flow between a rotating 360 degree helical electrode and a stationary, sacrificial, straight edge electrode separated by a 'wet' electrosensitive paper. The paper is 18 inches wide in a 300 ft roll and is automatically advanced to give a marking density of 90 sweeps, or lines, per inch. The paper dries to a permanent but not lightproof record and on doing so shrinks in width by up to one inch. The rate of rotation of the helix is controlled by a crystal derived frequency and a three speed gearbox. The standard rates are one half, one, and two rotations per second. Access is provided for an



I.O.S. Mk III PRECISION ECHO SOUNDER

FIG. 3. THE FUNCTIONAL LAYOUT OF THE MUFAX RECORDER

external drive frequency of around one kilohertz and 2.5V peak to peak. This is used to alter the sweep rate to distinguish one beacon in the presence of others. The sweep rates used are between 0.94 and 1.18 seconds per sweep. The shorter period is restricted by the synchronous motor drive to the helix. The signal is recorded as a series of horizontal lines which vary in appearance from white, through grey, to black according to signal strength. This range is covered by an 18 dB variation in signal voltage. The total signal range required by the system specification is approximately 60 dB. The tuned amplifier output is variable in 6 dB steps over this range to enable convenient matching to the recorder. This amplifier is centred on 10.2 kHz and has a bandwidth which may be varied using the Pulse length switch from 1 kHz in 0.7 ms and 1.4 ms positions, 350 Hz in the 2.8 ms position, to 200 Hz in the 5 ms position. Transducers can be connected to this amplifier through the main Plessey socket at the back of the Mufax (transformer coupled with variable impedance) or through the 130 ohm BNC external signal input socket on the front of the recorder (for more details refer to PES Mk III handbook).

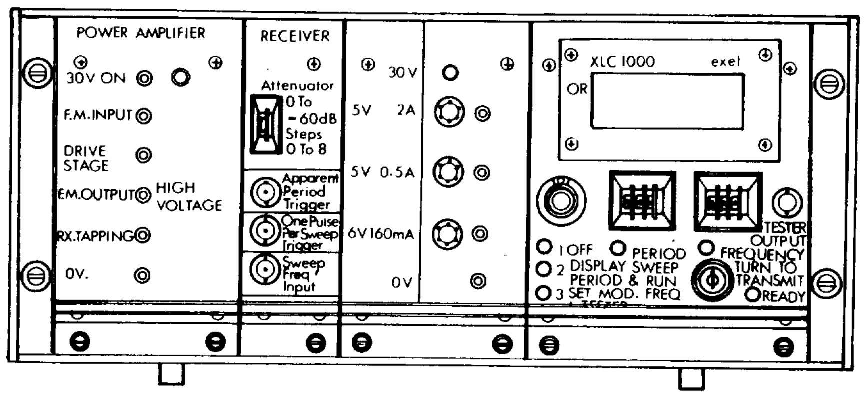
The PES amplifier incorporates a time varied gain facility for use while echosounding; this should be switched out during normal beacon operations. The marking amplifier of the recorder is independently accessible by means of the auxiliary input BNC socket at the rear of the recorder. This accepts signals of from 300 Hz to 15 kHz and may be accessed without influencing the internal amplifier. The input should be capacitively coupled and marks with signals from 0.25V to 4.0V peak to peak.

Other recorders used with the Mark III system are manufactured by EPC, Raytheon, and Gifft as geophysical or spectrum analyser displays. Any recorder of this type may be used but most will require matching amplifiers to display 10 kHz signals and generation of different frequencies if the full range of sweep rates are required.

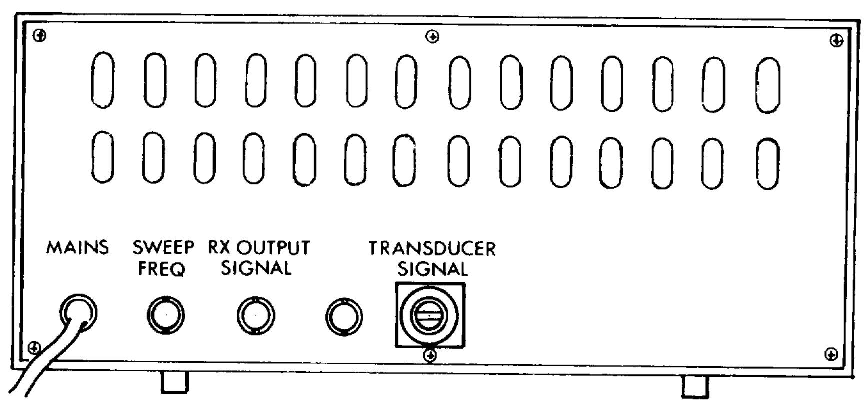
Advantages of the facsimile type paper recorder: they produce 'hard' copy immediately; the sweep to sweep time correlation of signals permits resolution of signals otherwise lost in noise. Operators can distinguish relatively easily between direct, reflected and refracted signals by observation of their appearance and behaviour. Trends are easily distinguishable such as doppler shift indicating movement relative to remote beacons. A variety of parameters may be monitored simultaneously and easily in real time. Recorders are frequently available through other applications such as echosounders and seismic work.

FIG. 4 THE DECK CONTROL UNIT Mk III

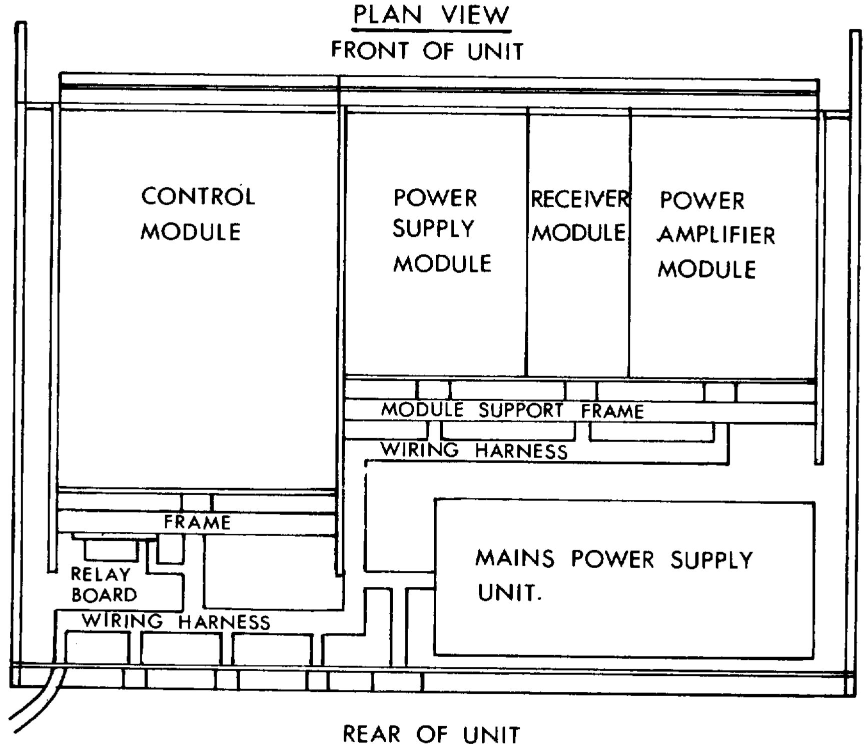
FRONT VIEW



REAR VIEW



PLAN VIEW



Disadvantages of the facsimile type paper recorder: wet paper shrinks and dry paper has an offensive smell; resolution is restricted by paper width; calibrated scales must be produced for each recorder and data measured by eye and recorded by hand; working up recorded data is very time consuming; recorders using 18 inch paper are large, heavy and expensive.

4. Deck Control Unit Mark III

4.1 General Description

The Deck Control Unit (Figs. 4 and 5) generates command signal for transmission by the electroacoustic transducer, amplifies signals received by that transducer to a level suitable for driving the facsimile recorder, and generates a range of frequencies suitable to synchronise the recorder with received signals.

The unit is built in modular form using the Vero D series range. The Mains operated power supply module is an Advance PMA51 high reliability unit mounted in the back of the case. The command signal and recorder sweep frequency are generated in the control module. They are derived from a 320 kHz crystal oscillator and monitored by a self-contained counter timer (EXCEL-XLC500) which has its own internal 10 MHz crystal oscillator reference. Transducer matching and power amplification of command signals is carried out in the Power Amplifier module which is supplied by the PMA51's 30V 3A regulated D.C. output. Supplies for the logic, switching relays, and monitoring counter are supplied by the Secondary Power Supply module from a 10 Volt A.C. tapping on the PMA51's transformer. Received signals are amplified and conditioned in the Receiver Module which also contains facilities for generating a variety of monitor trigger pulses.

4.2 Control Module

The Control Module (Figs. 6 and 7) has three functions: to generate 10 kHz frequency modulated (FM) command signals; to generate frequencies suitable to synchronise the recorder with a variety of beacon rates; and to independently monitor the operation of these two functions.

Steps in the generation of the FM control signal are (a) a phase locked loop which locks the modulation frequency to a crystal derived reference, (b) a custom designed shaping circuit which produces the modulation frequency as an approximate sine wave, and (c) a voltage controlled oscillator centred on 10 kHz, modulated in frequency by the sine wave.

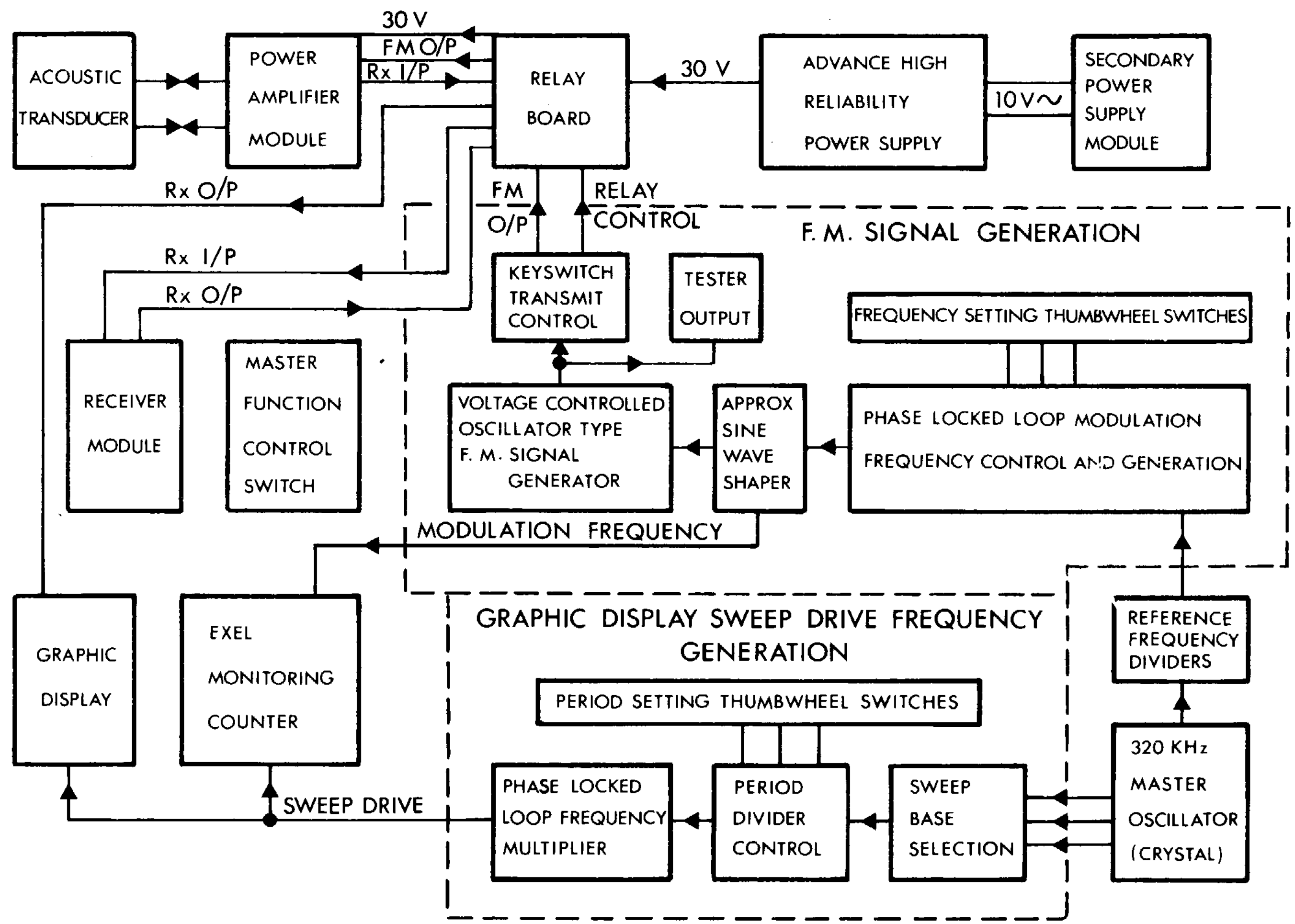
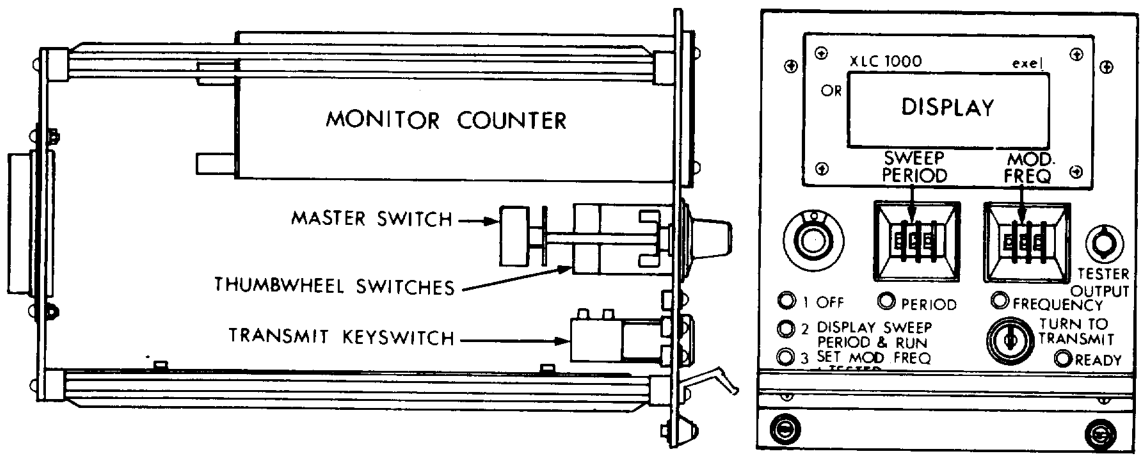


FIG. 5. DECK CONTROL UNIT FUNCTIONAL DIAGRAM

FIG. 6. CONTROL MODULE – PHYSICAL AND FUNCTIONAL PHYSICAL CONSTRUCTION



SIDE VIEW

FRONT VIEW

FUNCTIONAL CONTROL SEQUENCE

MASTER SWITCH POSITION 1

- RECEIVER ON
- SWEEP FREQUENCY OFF
- F.M. CARRIER OFF
- TRANSMIT KEY DISABLED
- MONITOR COUNTER OFF

MASTER SWITCH POSITION 2

- RECEIVER ON
  - OUTPUT APPLIED TO REAR SOCKET
- SWEEP FREQUENCY ON
  - PERIOD SET BY THUMBWHEELS
    - OUTPUT APPLIED TO REAR SOCKET
- F.M. CARRIER ON
  - MOD FREQ SET BY THUMBWHEELS
    - OUTPUT APPLIED TO TESTER SOCKET
- TRANSMIT KEY ENABLED
  - GATES F.M. CARRIER TO POWER AMPLIFIER F.M. INPUT
- MONITOR COUNTER ON
  - DISPLAYS SWEEP FREQ AS PERIOD IN SECONDS

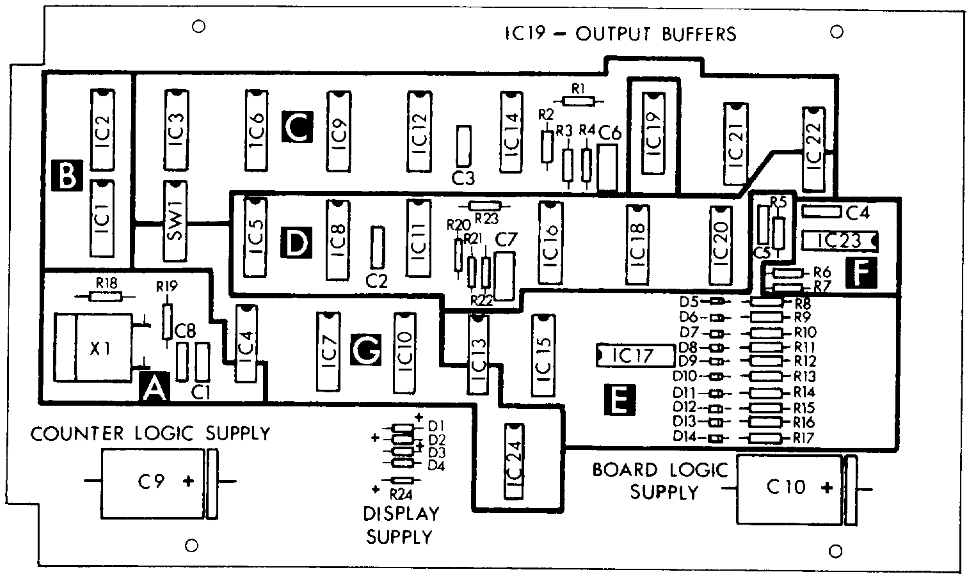
MASTER SWITCH POSITION 3

- RECEIVER ON
  - GATED BY TRANSMISSION RELAYS
- SWEEP FREQUENCY ON
  - AS POSITION 2
- F.M. CARRIER ON
  - AS POSITION 2
- TRANSMIT KEY ENABLED
  - AS POSITION 2 AND GATES THE TRANSMISSION RELAYS TO APPLY POWER TO THE POWER AMPLIFIER
- MONITOR COUNTER ON
  - DISPLAYS MODULATION FREQUENCY IN HERTZ

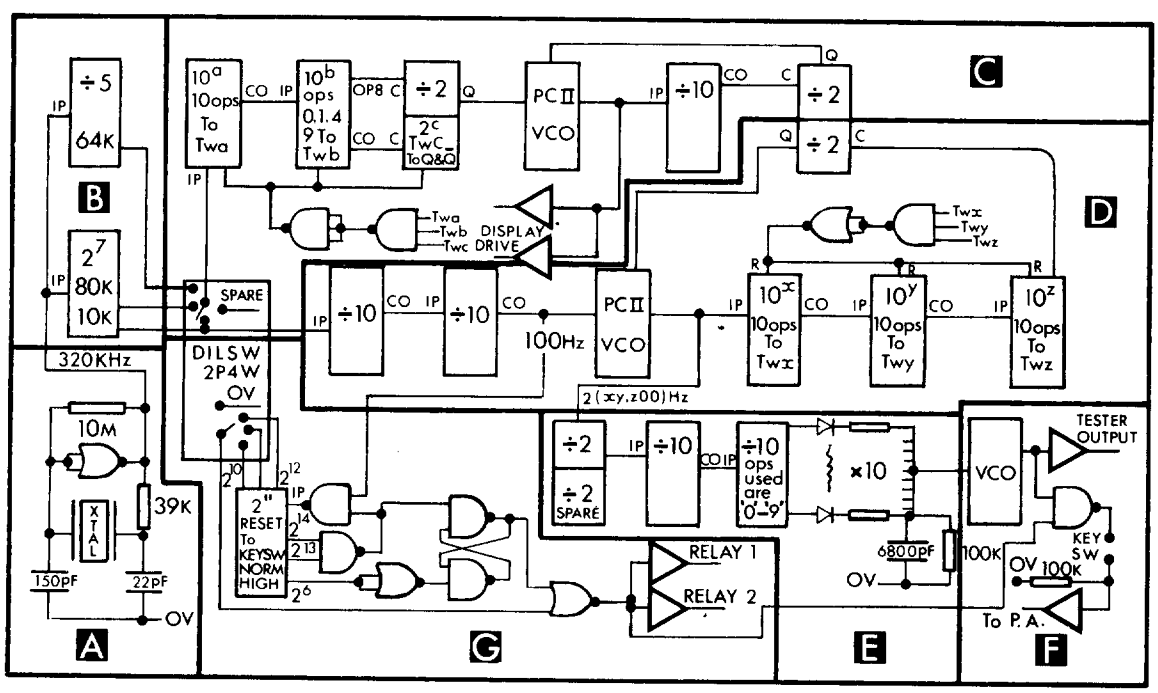
The phase locked loop (PLL) oscillator operates at 200 times the modulation frequency. This frequency is divided down by a divider chain which is programmed by three thumbwheels mounted in the front panel. The resulting frequency is then divided by two to produce an even mark space ratio signal and fed to 'Phase comparator II' on the PLL chip. This compares the signal with a 100 Hz signal divided down from the 320 kHz master oscillator and uses the difference signal to alter the PLL oscillator frequency to minimise the difference. The settling time of the system is less than one second. The resulting stable frequency is divided by 20 and fed to another free running decade divider. The ten sequential outputs are buffered by diodes and used to drive a succession of potential dividers. One arm of the divider is common, but the others are sequentially stepped and weighted such that the resulting output voltage waveform resembles a sine wave. The shaping is further assisted by a capacitor in parallel with the common arm removing the sharp stepped nature of the basic waveform which satisfactorily mimics a sine wave over the range required. This waveform is then used as the modulating signal to a voltage controlled oscillator (VCO). The VCO bandwidth is set by two resistors and centre frequency by a capacitor. The VCO is set to sweep from 9 to 11 kHz at 500 Hz modulation frequency and not more than 8.5 to 11.5 kHz at 200 Hz modulation which are the limits of the acceptance band of the sea unit electronics.

The output from the VCO is taken via a buffer to a BNC socket labelled Tester output on the front panel. This is for driving the 'clip on tester' for checking sea units acoustically in air, and via a capacitively coupled lead directly to the sea unit electronics for alignment and tuning. The output from the VCO to the power amplifier is gated by timing circuitry, the master function switch, and the 'Turn to transmit' key switch. The timing circuitry allows a variety of transmission intervals to be selected by an on board Dual in line four position (3 on early units) switch. The sequences are 5 seconds on, 5 seconds off, 10 on, 10 off, 20 on, 20 off, or continuous transmission, all for a total period of two minutes. The keyswitch 'enables' the VCO output and resets the gating circuit which then allows the PLL two seconds to settle before enabling transmission. The gating circuit also switches the relays controlling the power supply to the power amplifier and the inputs and outputs from the receiver module (to avoid overloading the receiver or recorder circuitry). The relay power supply is only enabled in master function switch position 3 which also switches the monitoring counter to the modulation frequency.

FIG. 7. CONTROL MODULE – CONTROL BOARD



PHYSICAL LAYOUT



LOGIC ARRANGEMENT

- **A** 320KHz CRYSTAL OSCILLATOR
- **B** PRIMARY DIVIDER CHAIN
- **C** SWEEP FREQUENCY GENERATOR
- **D** MODULATION FREQUENCY GENERATOR
- **E** MODULATION FREQUENCY SHAPER
- **F** CARRIER FREQUENCY GENERATOR
- **G** TRANSMISSION GATING CIRCUIT

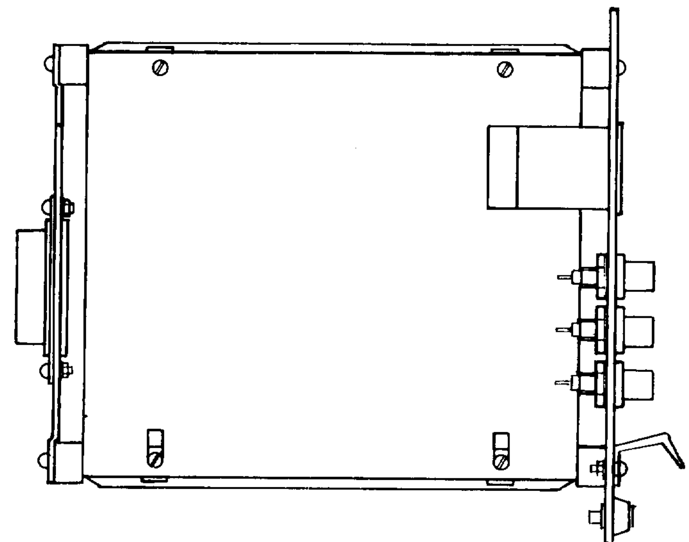
Generation of the recorder drive frequency is achieved using (a) a reference frequency derived from the 320 kHz master oscillator, (b) a programmable divider chain to adjust the frequency in the required increment, and (c) a phase lock loop multiplier to return the frequency to the required range. Three reference frequencies are generated in the standard unit and are selectable by an on board four position switch. The three base frequencies are 1 kHz (for the Mufax recorder), 8 kHz (for the two stylii EPC recorder) and 6.4 kHz (for the three stylii EPC recorder). The actual frequencies switched are ten times these and provision (except in early units) is made for introduction of other frequencies through the unused position. The programmable divider chain consists of two decades and a single stage binary counter set by adjusting the thumbwheels on the front panel to the beacon repetition period required. The resulting frequency is of uneven mark space ratio and a factor of ten too slow so it is shaped by a single stage binary divider, then multiplied by 20 using a phase locked loop. The period of this frequency is monitored by the monitoring counter when the master function switch is in position 2. It should read as the thumbwheel setting when the Mufax frequency is selected but a factor of 6.4 or 8 smaller when used with the EPC frequencies. The buffered drive is available from the 'Sweep freq' BNC socket at the back of the Deck Control Unit.

All control unit circuits are CMOS. The master function switch 'enables' the logic and the monitoring counter in positions 2 and 3. The command signal gating relays are mounted on a PCB by the control module socket on the mainframe. The relays are two-pole, two-way units as used in the CR200 series sea units and are switched by transistors. The monitoring counter circuits are TTL and fully described in the XLC500 handbook.

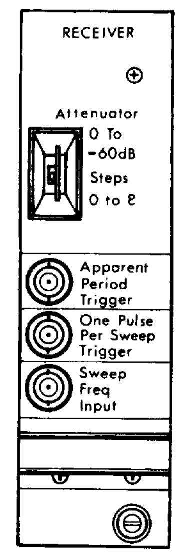
4.3 Receiver Module

The receiver (Figs. 8 and 9) incorporates: a nine stage (60 dB) input attenuator, a low noise high gain preamplifier, driving in parallel via a unity gain buffer, a pair of highly selective active biquadratic filters tuned to the beacon reply frequency 10.00 kHz and a transponder reply frequency 10.66 kHz. The outputs of these filters are used to provide the display signal and are also rectified, integrated, then via voltage comparators used to indicate incoming pulses. These can be used to trigger a counter which in measuring the apparent beacon period indicates the doppler shift or relative approach to that beacon. Also in this module is divider circuitry for providing display trigger pulses in synchronisation with the expected incoming beacon pulses from the 1 kHz, 6.4 kHz or 8 kHz generated by the control module.

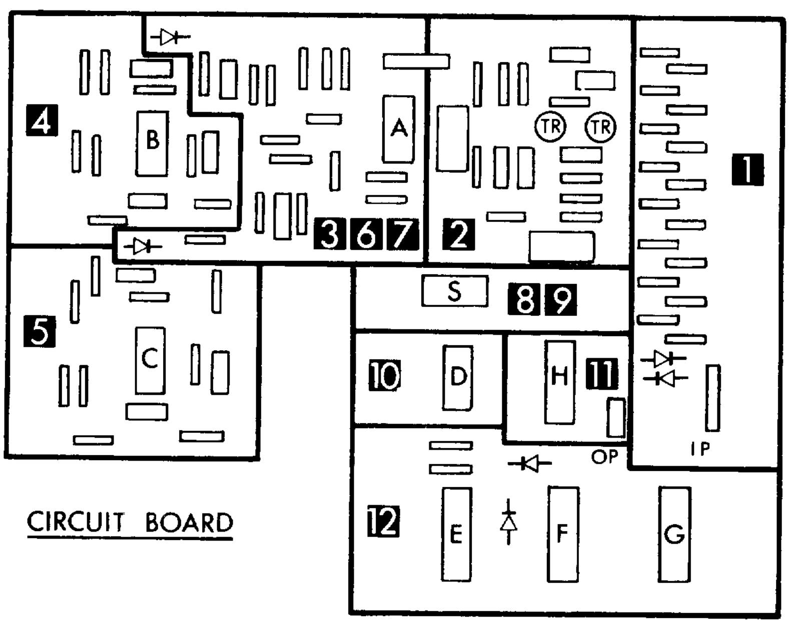
FIG. 8. RECEIVER MODULE – PHYSICAL AND FUNCTIONAL



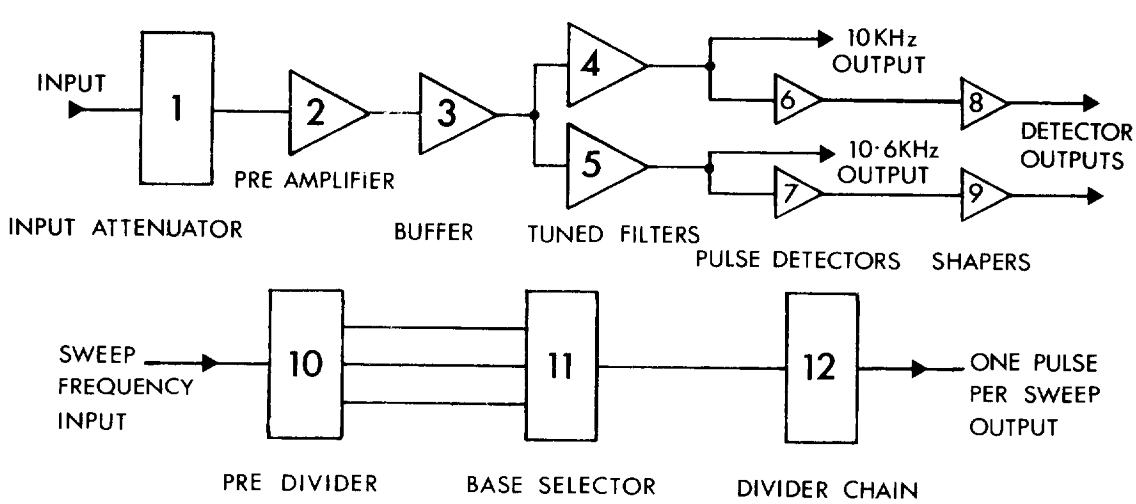
SIDE VIEW



FRONT VIEW



CIRCUIT BOARD



The input signal from the electroacoustic transducer is matched to the preamplifier using the transformer in the power amplifier module and a resistor-capacitor combination. The series resistor is of six watts capacity and followed by high voltage back to back diodes to cope with the power dissipated in this winding when the deck unit is transmitting the continuous interrogation signal. The input attenuator intercedes between diodes and capacitor and is an eight stage resistive ladder. The attenuator is switched using a ten position thumbwheel mounted in the module front panel. Position 0 is the minimum attenuation position, positions 8 and 9 are commoned and are approximately 60 dB down on position 0, intervening positions are separated by approximately 8 dB.

The preamplifier is wideband as used in the CR200 series sea unit. It uses two BC109C low noise, high gain transistors producing an overall voltage gain of 60 dB. To prevent this circuit being loaded by the tuned stages it is capacitively coupled to a unity gain operational amplifier. The tuned circuits are DC coupled to the buffer, the series resistors controlling the overall gain of the system. To avoid significant interaction between the two circuits a practical minimum of 10KΩ per resistor has been established. The tuned stages are of the active biquadratic design described in Siliconix Application Note (AN74-6). They use three operational amplifiers and are tuned by varying two resistors (chosen for convenience to be each a series pair) and two capacitors. The practical operational amplifiers chosen are the Siliconix L144CJ - three being contained on one 14 pin, dual-in-line package. To obtain the required slew rate a set current of 250nA is required, obtained using a 470KΩ setting resistor, and the phase compensation capacitor, C_C, used is 100pF. The gain of the filter is up to 36 dB, the Q is 35 and the roll off is 18 dB at 1 kHz either side. The circuit consumption is around 300μA at 5V. The tuned circuits require a mid-range voltage reference point obtained as in the CR200 series sea units by use of two large R-C circuits in series.

The outputs of the two tuned circuits are wired to one switch of four one-pole two-way switches mounted in a 14 pin dual in line package on the board. This switch is used to select the 10.0 kHz or 10.66 kHz outputs to be capacitively coupled to the usual receiver output of the deck unit.

The outputs are also rectified, integrated and coupled to separate operational amplifier voltage comparators. These comparators are set to ignore the remnant DC bias level plus 1 volt peak to peak superimposed

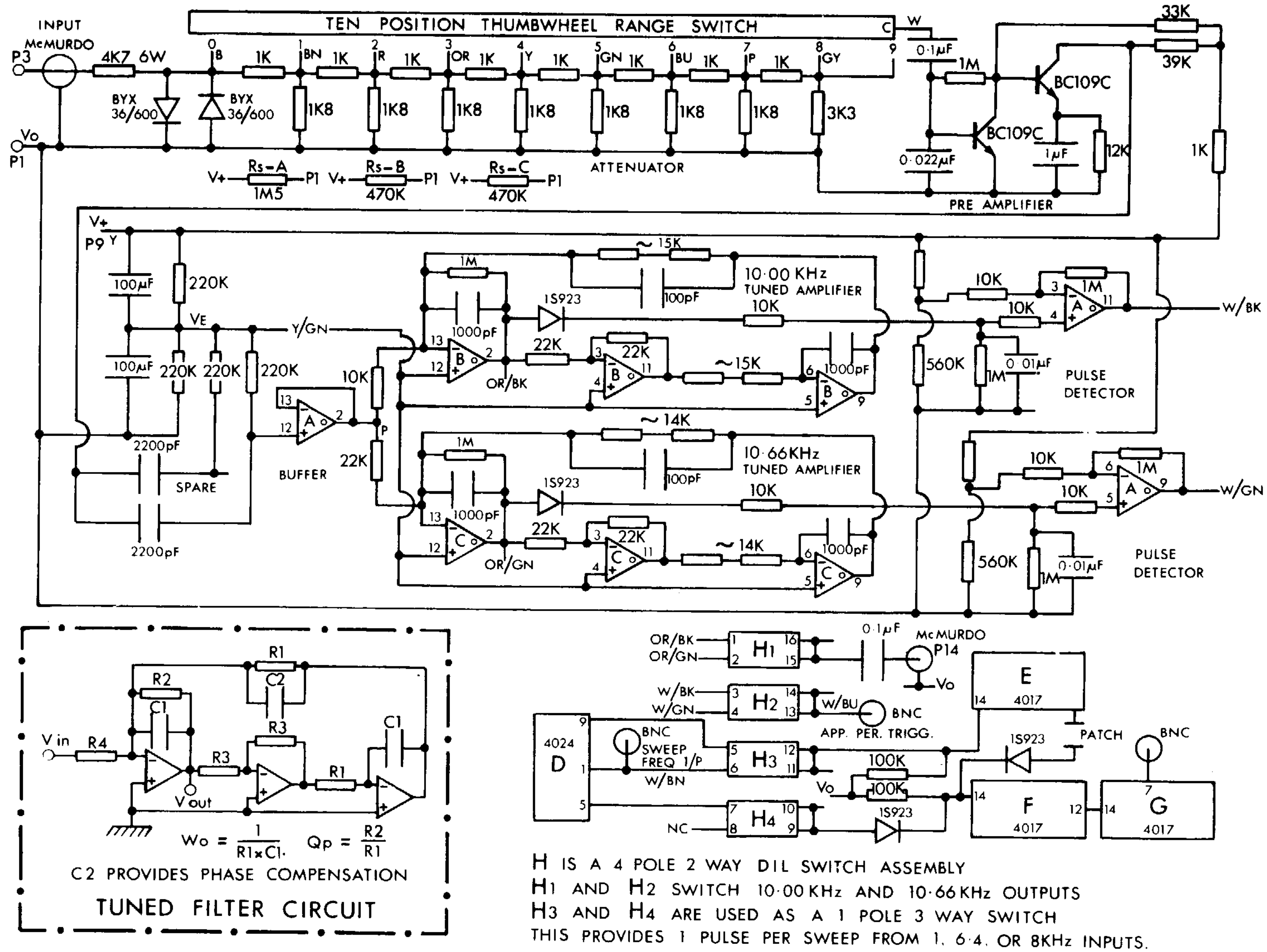


FIG. 9. RECEIVER MODULE – ELECTRONIC DESIGN

signal. Thus all signals above this level will trigger the comparator. Under most conditions, except extreme range and abnormally high sea noise, the attenuator tuned amplifier combination may be easily set to provide outputs from the comparator only from incoming beacon pulses (or the occasional high sea noise spike). The comparator output is made available at the 'Apparent Period Trigger' BNC connector on the module front panel. If this is connected to a counter set to period, successive pulses will register the period of pulses being received by the system. If this period is less than the known crystal derived period of the beacon, approach is indicated, if more then recession. The magnitude of the difference is also a measure of the rate of relative motion. If the counter input is disabled during interrogation pulses the same technique may be used with the transponder. The outputs of these comparators are wired via another of the on board switches to the one BNC connector.

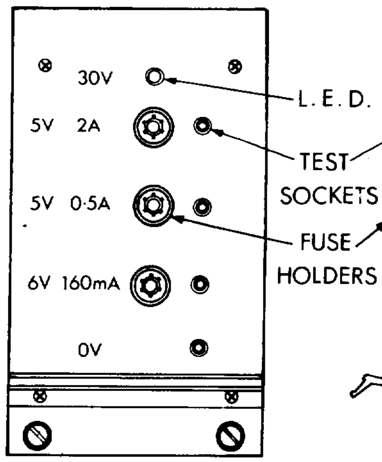
The other function of this board is essentially unconnected with the receiver functions but is extremely useful when observing the receiver outputs on displays such as oscilloscopes. It comprises a divider chain which provides a single pulse output at the expected incoming beacon pulse rate from the frequency generated to drive the facsimile displays in synchronisation with that pulse rate. This can be used to trigger oscilloscope sweeps in synchronisation with selected incoming pulses.

The divider chain is programmed using the two remaining on board switches as a complex three input, two output switch using only one wiper, the other being permanently 'parked' at an unconnected input. This will cope with the three control module frequencies based on 1 kHz, 6.4 kHz and 8 kHz. The input frequency is derived from the 'Sweep Frequency Output' BNC at the back of the deck unit. It is fed to the dividers through the 'Sweep Frequency Input' on the front of the module. The trigger pulse output is a 5V pulse at the 'One Pulse per Sweep Output' BNC on the front of the module. The repetition period will be that of the period dialled on the thumbwheels on the front of the control module.

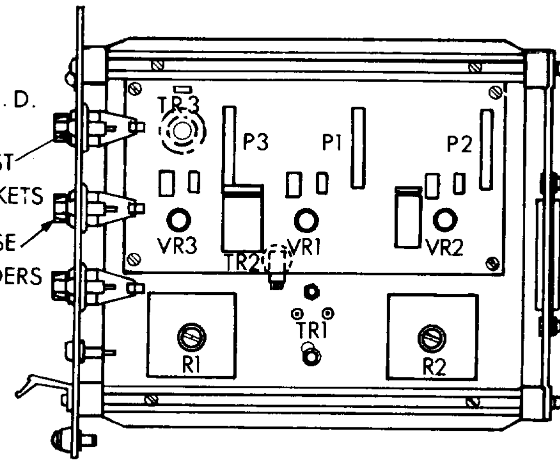
4.4 Power Supply Module

The power supply module (Fig. 10) rectifies the 10V A.C. supply from PMA51 transformer and provides a regulated supply for the control logic, receiver module, relay board, and monitoring counter logic and an unregulated supply for the monitoring counter display. It also refers these supplies to the 0V rail of the 30V supply and indicates operation of the 30V supply.

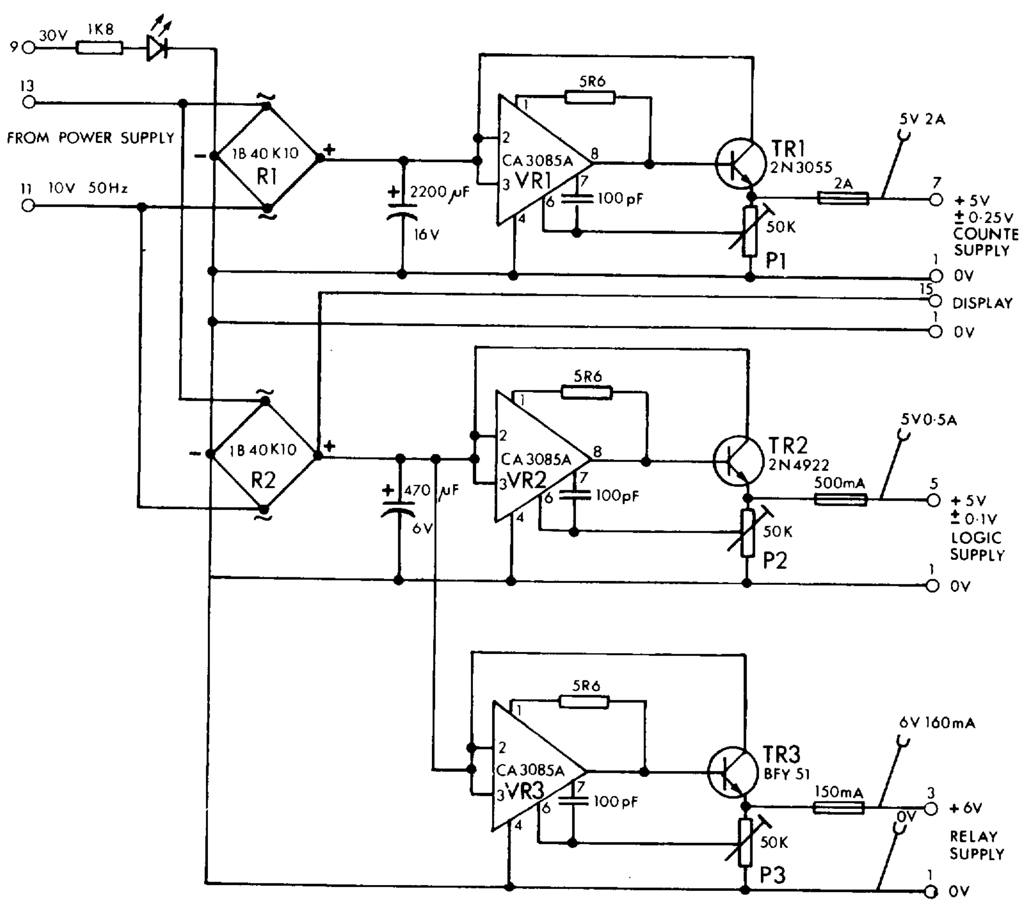
FIG. 10 POWER SUPPLY MODULE



FRONT VIEW



SIDE VIEW



ELECTRONIC CIRCUIT

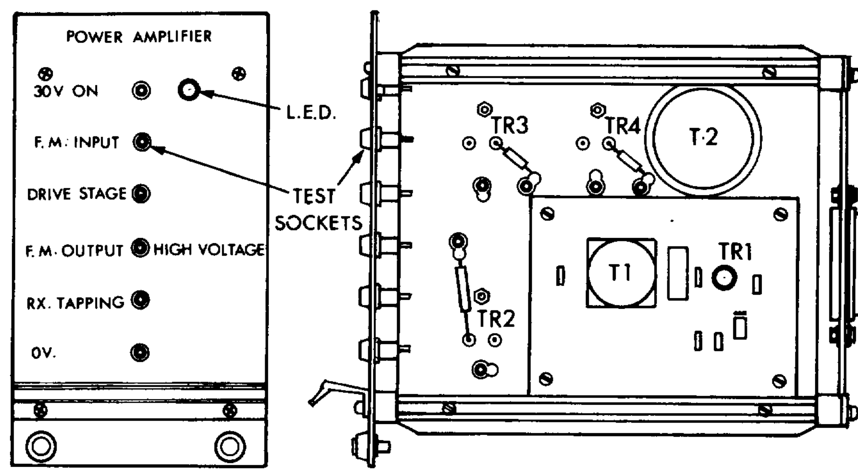
The 10V A.C. supply is fed to two full wave silicon rectifiers in parallel. The output of one rectifier is regulated to 5V using a standard voltage regulator (RCA-CA3085A), buffered by a high power transistor and used to operate the monitoring counter logic via a two amp fuse. The voltage is adjusted by feedback from a potentiometer in the emitter circuit of the power transistor. The second rectifier unregulated output is supplied to the Master counter display and two regulating circuits. These circuits are basically the same as the previous design but use smaller output transistors. One provides 5V via a 500 mA fuse to the Control logic and the receiver module, the other provides 6 volts via a 160mA fuse to the relay board. 30V supply operation is indicated by an LED and series resistor between the 30V positive rail and the common 0V. Adjustment is the same for all three regulated supplies. The 5V 500mA supply must be 5V ± 0.1V or the command signal carrier frequency moves out of the sea unit acceptance band. The other supplies are not as critical.

4.5 Power Amplifier Module

The power amplifier module (Fig. 11) performs two functions. One function is to amplify the frequency modulated command signal to drive the PES Mk III single element transducer at sufficient power to obtain the range required of the system. The second function is to match the transducer to the receiver module to obtain the sensitivity to incoming signals required of the system. These functions require different conditions to optimise their respective performances. If operation with ceramic-ring type transducers is required usable results are obtained with the system as it is, but a special matching stage is recommended for optimum performance.

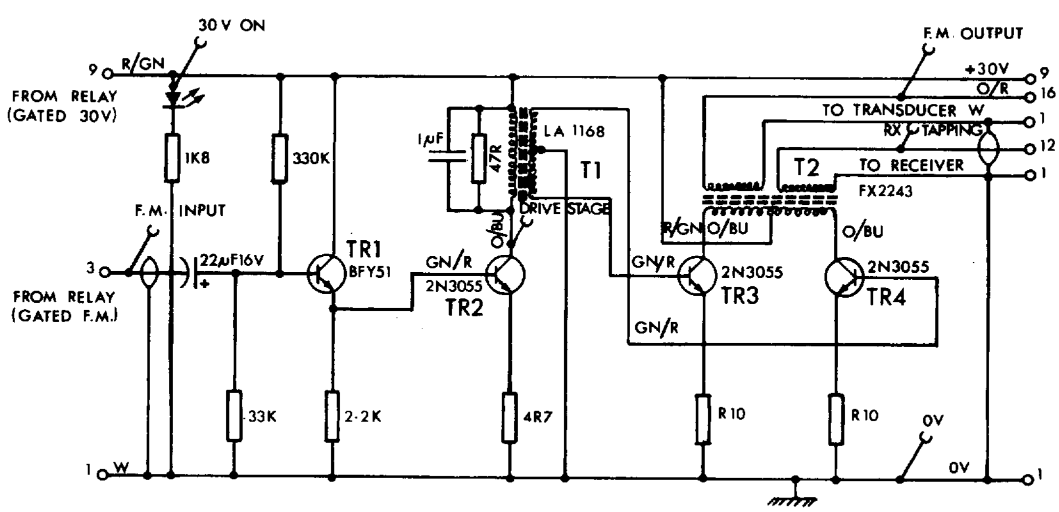
In the standard arrangement the transducer is operated as a transceiver using a three component matching transformer to separate its two functions. The tasks of this transformer are to match the impedance presented by the transducer and its associated cable to the impedances of the input stage of the receiver module and the output stages of the power amplifier. These requirements are different and achieved by use of different turns ratio, a fixed air gap to tune the inductance, and the addition of a small capacitor to the transducer circuit when transmitting. This capacitor must be removed if optimum receiver performance is required. The capacitance required is selected by adjusting the value of a capacitor applied between the FM output monitoring point and the 0V point on the module front panel until the signal observed at the monitoring point shows minimal distortion. This is the point of maximum useful power conversion. The value will vary with the length and type of cable used between the deck unit and transducer.

FIG. 11. POWER AMPLIFIER MODULE



FRONT VIEW

SIDE VIEW



TRANSFORMER T1			
DUST CORE	MM 724/138/S1		
ASSEMBLY	MM 734 A		
WINDING – PRIMARY		43T	24 SWG
– SECONDARY		10–0–10T	24 SWG

TRANSFORMER T2			
DUST CORE	FX 2243		
ASSEMBLY	DT 2152		
WINDING – PRIMARY		10–0–10T	20 SWG
– RECEIVER COIL		40T	24 SWG
– TRANSDUCER COIL		60T	24 SWG

ELECTRONIC CIRCUIT

The transformer receiver tapping is wired to the monitoring point on the front panel and to the socket on the back of the module. The input to the power amplifier is also monitored on the front panel and is capacitively coupled to a low power buffer stage. This buffer stage is emitter coupled to a medium power driver stage. The collector load of the driver stage is tuned to 10 kHz and transformer coupled to drive the high power output stages. These output stages operate in a push-pull configuration to drive the transducer via the matching transformer. The power amplifier module draws approximately 35 watts of D.C. power to deliver 20 watts A.C. to the transducer circuit without the tuning capacitor and draws 60 watts from the D.C. supply to deliver 45 watts to the transducer circuit with the tuning capacitor. When the power amplifier is transmitting a red LED is illuminated on the front panel.