INSTRUCTIONS FOR THE INSTALLATION, OPERATION AND MAINTENANCE OF THE BENTHOS MODEL TR-7000 RECOVERABLE ACOUSTIC TRANSPONDER

M-600-002 Rev. 2

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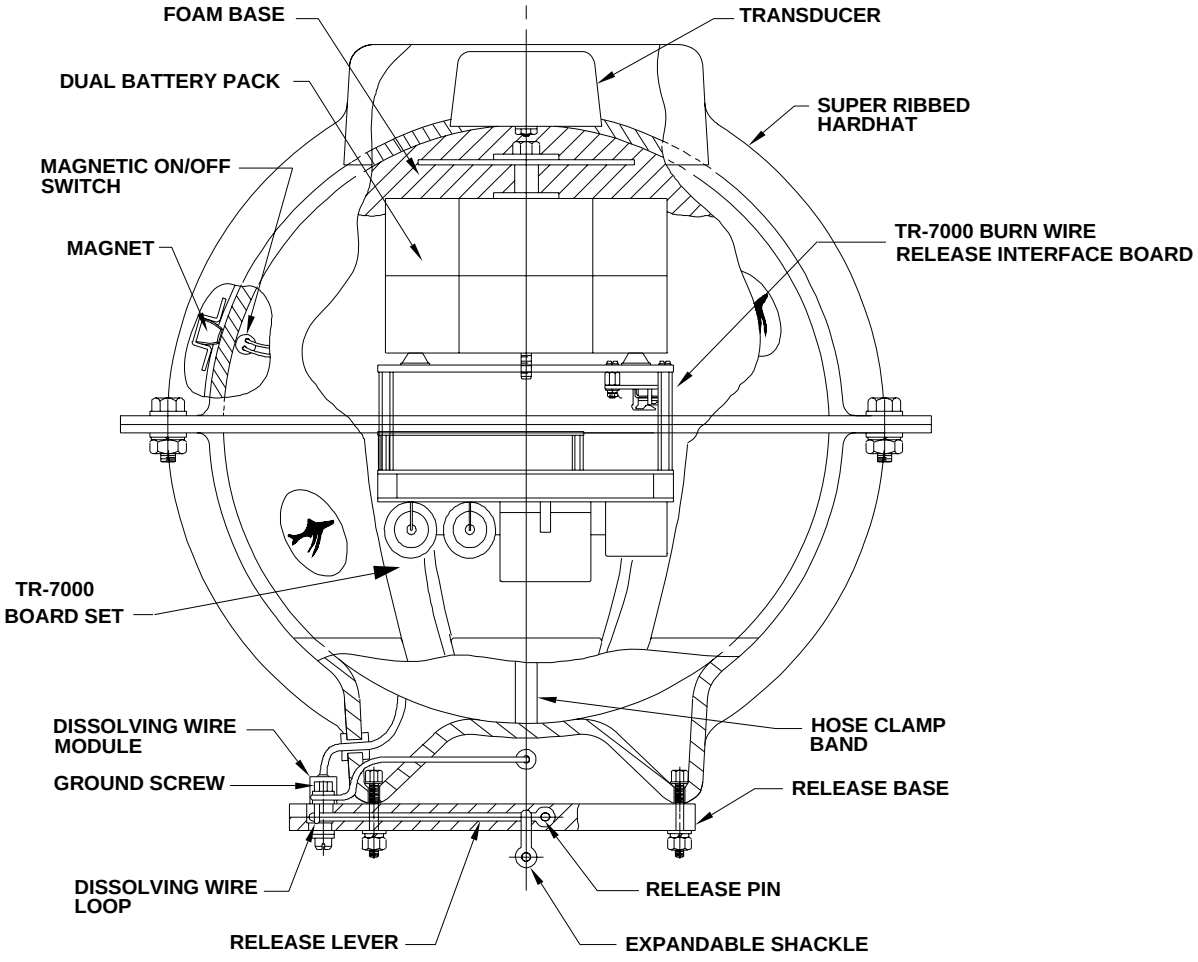
1.0 INTRODUCTION

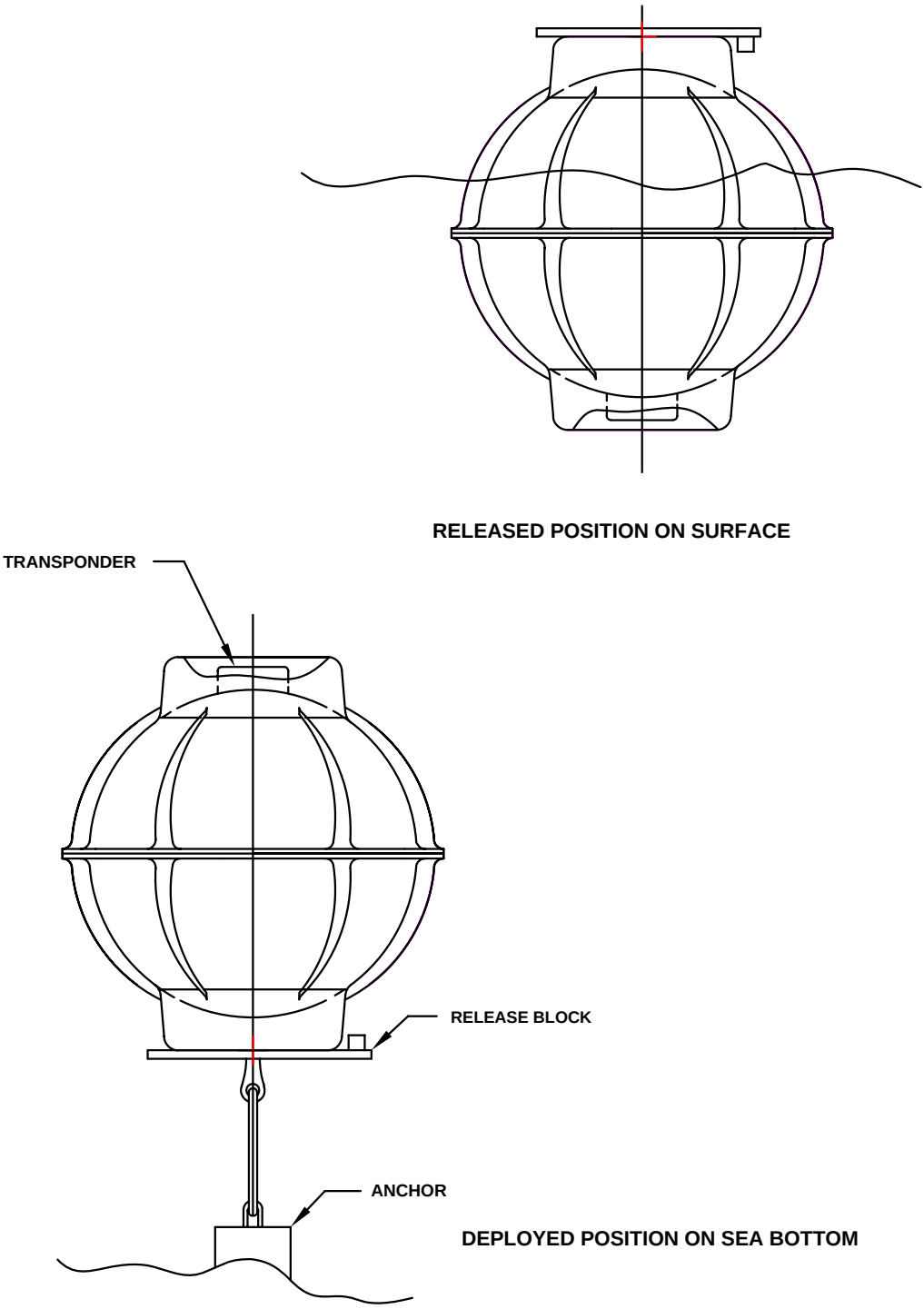
This manual contains the specifications and operation instructions of the Benthos TR-7000 Recoverable Acoustic Transponder.

The TR-7000 Transponder, shown in Figure 1-1, consists of a deep sea acoustic transponder in a 17-inch glass housing and a 17-inch super ribbed hardhat. A releasing mechanism, bolted to the bottom of the hardhat, provides a 12:1 mechanical advantage, and includes a release lever which is tripped by a dissolving wire when activated by the acoustic transponder. The entire assembly is a self-buoyant package which will flip over from the transducer - up position when deployed to the transducer - down position when released and on the surface (see Figure 1-2). Two molded handles in the hardhat are provided for ease of recovery and shipboard handling.



TR-7000 Recoverable Acoustic Transponder

Figure 1-1



Deployed/Released Positions of the TR-7000

Figure 1-2

The Model TR-7000 uses the 7000 Series Transceiver Electronics Board Set.

The TR-7000 is intended for acoustic navigation and release of light loads at a 22,000 foot (6700 meter) water depth. For ease of relocation, the unit will transpond when interrogated to determine slant range, and will transpond in different modes for confirmation of release.

Interrogations and commands are transmitted by a Model DS-7000 Deck Unit, which also provides a four-digit readout of slant range up to 33,000 feet (10,000 meters). The deck unit can provide all available interrogate frequencies and eight different command codes per receiver frequency. The Model DS-7000 Deck Unit has its own manual and is not described in detail here (see Figure 1-3).

DS-7000 Acoustic Deck Unit

Figure 1-3

Upon completion of a RELEASE command, the TR-7000 will change its transponder reply from one to four pings for every interrogate pulse from the deck unit. At the deck unit, the verification that the RELEASE command has been received and acted on is seen as multiple flashes of the Receive LED and the data displayed for the multiple evenly spaced pings. The TR-7000 reverts to a single ping when the unit is re-armed.

Upon recovery, the transponder can be re-armed and used again. The standard battery pack will easily provide six months use with many releases and a minimum of 300,000 transponds. The TR-7000 reverts to a single ping when the unit is re-armed.

In order to ensure the maximum battery life of the TR-7000, there is an integral transpond enable/disable feature. After a predetermined time, the transpond capability is automatically disabled. This prevents unintended pings which would waste energy. By sending an ENABLE command the timer is reset and the TR-7000 will again reply when interrogated.

Included in this manual are all the necessary instructions to:

- Open and close the glass housing
- Change the transmit frequency
- Change the battery pack
- Change the receiver lockout time
- Change the transmit pulse length
- Change the receive frequency.

Also included is a Theory of Operation.

2.0 SPECIFICATIONS

2.1 Configuration and Dimensions

17-inch Glass Instrument Housing in Super Ribbed Hardhat.
24-inch maximum diameter x 22½ inch maximum height.

2.2 Weight in Air

60 pounds (26 kg).

2.3 Buoyancy in Seawater

38 pounds (17 kg).

2.4 Maximum Depth Rating

22,000 feet. All units are factory tested to 22,000 feet (6700 meters).

2.5 Operating Range

10 km slant range with Benthos Model DS-7000 Deck Unit.

2.6 Transducer Pattern

Near omnidirectional from upper hemisphere. See Appendix A.

2.7 Receive Frequencies

The receiver frequency is factory set in EEPROM to any one frequency between 7.0 Khz and 15.0 Khz in 250 Hz increments to be compatible with the DS-7000 deck unit. The inherent resolution which can be set is 16 Hz. The receiver bandwidth is ± 125 Hz. The frequency can be changed at any time using an RS-232 cable and most terminal emulation programs using simple built-in commands.

2.8 Transmit Frequencies

Transmit frequency is set in EEPROM to frequencies between 7.5 Khz and 17 Khz in 250 Hz increments to be compatible with the DS-7000. Inherent frequency setting quantization is 16 Hz. The frequency can be changed at any time using an RS-232 cable and most terminal emulation programs using simple built-in commands.

2.9 Minimum Detectable Signal

Less than 85 dB re 1 upascal.

2.10 Source Level Output

Greater than 192 db re 1 micropascal at 1 meter from 9.0 to 13.0 Khz.

Greater than 185 db from 7.5 to 8.5 Khz., 13.0 to 17 Khz.

2.11 Detection Jitter (or repeatability)

±.4 milliseconds.

2.12 Receiver Lockout Time

1.5 seconds, re-triggerable, programmable from .5 to 127.5 sec (nearest .5 sec) by RS-232.

2.13 Transmit Pulse Length

10 ms ±1% is standard. Pulse width can be increased from 10.0ms to 26.5ms. via RS-232 command.

2.14 Turnaround Delay

10 ms (±.1ms) minimum and default, up to 52 ms programmable by RS-232.

2.15 Commands

Eight standard channels (A, B, C, D, E, F, G or H) are available from the deck unit which, in combination with the receive frequencies, provides 256 different codes of non-interfering operation. A-H command assignment is set at the factory in EEPROM, but can be reassigned by the user using the RS-232 interface.

RELEASE command is standard; ENABLE/TIMED DISABLE and ON/OFF commands are optional.

ENABLE TIME is set for 12 hours (±.1% as a default by the factory unless otherwise specified.) Enable time can be programmed from 1-99 minutes, hours, or days by RS-232 command.

2.16 Power Source

16 amp-hour alkaline battery pack.

2.17 Maximum Operating Life

Six months with 300,000 transponds, or one month with 350,000 transponds. Operating life specifications are based on 10 millisecond transmit pulse length. (See note below.)

2.18 Release Method

Electrolytic dissolving wire (upon receipt of correct command).

2.19 Release Indication

Changes from single to quadruple ping upon receipt of RELEASE command. Reverts to single ping when re-armed.

2.20 Disposable Anchor

Weight (in Seawater): 75 to 100 pounds (33 to 44 kg).

NOTE: Anchors not supplied by Benthos.

(Specifications subject to change without notice.)

2.21 Accessories

- TR-6000 RK Re-arming Kit
- TR-6000 SPK Spare Parts Kit
- Model DS-7000 Deck Unit
- Model 210-ADU Deck Unit
- TR-6000 Spare Battery
- A-500-77 RS-232 programming cable with ± voltage generator built into the connector.

NOTE: The maximum deployment time is rated to six months due to materials limitations. The internal alkaline battery pack is rated for a capacity of 16 amp-hours. The actual operating life of the transponder is dependent on standby drain, number of transponds and number of releases. The following numbers may be used to predict the appropriate battery drain:

Standby Drain: 0.022 amp-hours/day

Transpond Drain: 3.09E-05 amp-hours/transpond

Release Drain: 0.10 amp-hours/release.

3.0 GENERAL DESCRIPTION

3.1 Major Components

The Model TR-7000 Transponder is supplied to the customer with the major components as follows:

- Model TR-7000 Transponder in 17-inch Glass Instrument Housing in Super Ribbed Hardhat (17-inch SRO) with attached transducer and release mechanism. One (1) release link (¼ inch stainless shackle) and one (1) burn wire module should be installed in the release assembly.
- On/off magnet attached to release inside hardhat cutout
- Spare Re-arming Kit (see Section 8)
- Spare Parts Kit (see Section 8)
- Instruction Manual.

Upon receipt of equipment, the customer should check the shipment to insure that the order is received complete and undamaged. Please contact Benthos before returning any equipment damaged in shipment.

3.2 Construction

The Model TR-7000 Transponder consists of the printed circuit boards and battery pack fastened inside the self-buoyant 17-inch glass instrument housing. One penetrator through the glass housing is used to connect to the transducer in the upper hemisphere and two electrical penetrators through the glass housing are used for the dissolving wire electrodes. A hose clamp and bail assembly is used to hold the two instrument housing halves together. The entire glass assembly is enclosed in a two piece polyethylene hardhat. The top half has a cutout in the top for the transducer and the bottom half has the release assembly bolted to the bottom, as shown in Figure 1-1.

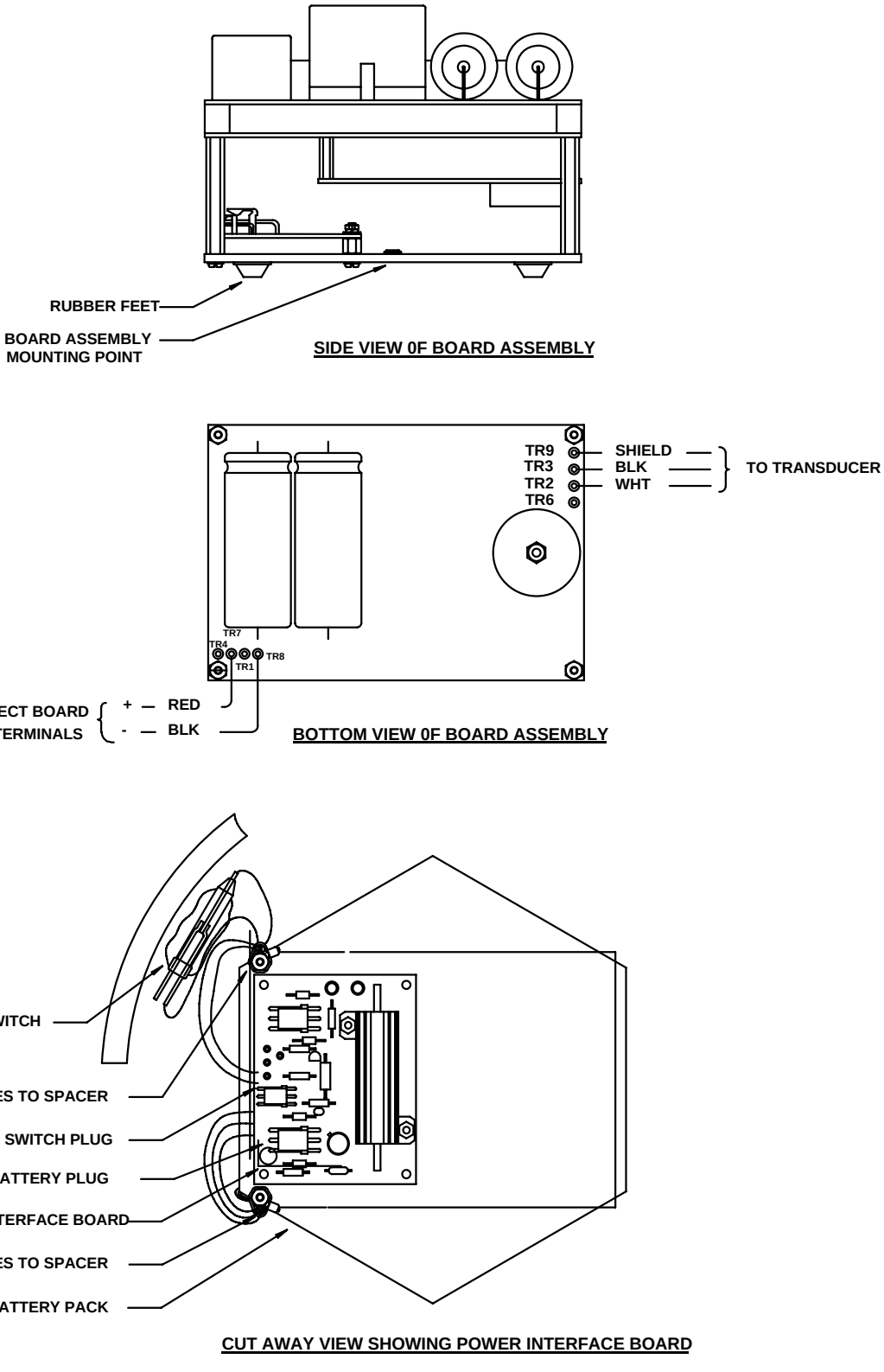
There are four circuit boards altogether. Two are back to back, separated by four spacers and a connector. A third smaller board, mounted on spacers, connects to the two back to back boards. One connector joins the three boards electrically. The fourth board is mounted separately to the mounting plate and contains the dissolving wire power circuit. See Figure 3-1.

1. TR-7000 driver Board, C-600-4 (with largest components)
2. TR-7000 CPU Board, C-600-3
3. TR-7000 Synthesizer Board, C-600-5.
4. TR-7000 Burn Wire Release Interface Board,

The transducer, dissolving wire release electrode wires, batteries, and the magnetic reed switch are all connected to the P.C. board assembly.

The transducer is a near-omnidirectional piezoelectric ceramic ring transducer molded in polyurethane and fastened by a center tube to the top hemisphere. The dissolving wire release electrodes are each attached to the release base on the bottom of the hardhat. The dissolving wire (the anode) is a cast polyurethane module containing a stainless steel wire loop connected to a female single pin connector. The module is fastened to the release base at the end of the release lever. The lever has a 12:1 mechanical advantage and pivots about a lever pin. The electrical ground (the cathode) is a bolt attached to the release base adjacent to the exposed wires of the release module. The cathode wire from the glass housing is fastened to the ground screw.

The magnetic reed on/off switch is attached to the inside surface of the glass housing adjacent to the match mark inside the cutout in the hardhat. A magnet (provided) fits inside the bracket on the hose clamp band. The unit is off when the magnet is installed in the band bracket.



P.C. Board Assembly

Figure 3-1

4.0 OPERATION INSTRUCTIONS

4.1 Surface Preparation

Prior to deployment, the TR-7000 Transponder should be:

1. Tested to confirm proper operation.
2. Rigged with a disposable mooring weight.
3. Confirmed that the on/off magnet is removed.

4.2 Testing

Before deployment, test that the unit is operational by using the following procedures.

4.2.1 Power On

Remove the on/off magnet from the hose clamp band bracket; this will turn the unit on. After about three (3) seconds, the unit will signal that it has been powered-up successfully by transmitting four pings about three seconds apart.

NOTE: The power-up pings will only occur if the magnet has been in place for about two minutes.

If you wish to turn the TR-7000 off again, simply place the magnet over the match-mark near the equator on the lower hemisphere. After approximately two minutes, the unit will not operate.

4.2.2 Single Transpond

a. Place your deck unit transducer near the TR-7000 transducer. Set the TRANSMIT FREQUENCY (Tx) to the receive frequency of the TR-7000 and the RECEIVE FREQUENCY (Rx) to the transmit frequency of the TR-7000. The receive and transmit frequencies are written on the external label of the TR-7000. However, since the TR-7000 is programmable, the frequencies may have changed. It is a good idea to keep a separate record of serial number and setup information to compare with the external label.

b. Send a single transpond from the deck unit. The TR-7000 should reply once simultaneously. Place your finger on the transducer and you will be able to actually feel the transmission.

   Note that the TR-7000 will not respond to transmissions within 1.5 seconds of each other. This is the standard LOCKOUT feature which prevents extra replies from multipaths.

   Also note that if the ENABLE time has run out, the TR-7000 will not reply at all. (See Sections 7.1.3 & 11.5.1.)

c. Change the Tx Frequency selected on the deck unit and now verify that the unit **DOES NOT** reply when interrogated. The unit should only respond to the proper frequency.

4.2.3 Command Enable

To test the ENABLE feature, transmit the DISABLE command or leave the TR-7000 ON until the Enable Timer runs out. This may be 12 hours (±.1%) for the default setting or from 1 minute to 99 hours, depending on how it has been programmed. Then verify that it will not reply when interrogated. Place the deck unit transducer very close to the TR-7000.
Next, send an ENABLE command and afterwards verify that the unit will reply when interrogated. To send a command, follow these steps:

a. Set the TRANSMIT FREQUENCY on the deck unit to the receive frequency of the TR-7000 being commanded.

b. In the Command Mode, select the code designated on the TR-7000 for ENABLE.

c. Send a command. During the middle of the command you may hear the TR-7000 ping once as it "wakes up". It waits until the command stops before executing the command.

d. Send a single transpond and verify that the ENABLE command was successful, i.e. the TR-7000 does reply. If not, move the deck unit transducer slightly and try another command.

NOTE: It is sometimes very difficult to get a command through the air. If you have trouble, do not panic! This is normal, as the system is designed to operate in water where the sound paths are more predictable. Simply move the transducers to slightly different positions, often a change of as little as one inch (1") is all that is necessary to make the difference. It may be helpful to line the test area with foam rubber to dampen reverberations.

Because of the long wait for the ENABLE timer it is not necessary to test this feature routinely. However, it is recommended that you test it at least once so that you are completely familiar with its operation. Alternatively, you may wish to temporarily program the Enable time for (M)minutes rather than (H)ours to perform this test. After the test the Enable time would normally be changed back to (H)ours. (D)ays are also allowed but not recommended.

4.2.4 Command Release

To test the RELEASE command, attach both leads of a voltmeter to the electrode wires; the positive voltmeter lead goes to the exposed portion of the burn wire loop and the negative lead to the ground screw. Send the proper RELEASE command from the deck unit. The RELEASE command lasts for about four seconds. After about two to three seconds into the RELEASE command, the RELEASE command will be received and the voltmeter will indicate approximately 25 volts until just after the command is over (or about two or three seconds more). If the measured voltage is less than 22 volts, the battery pack should be replaced. See Section 6.3 for checking and changing the battery pack.

NOTE: Receiving acoustic commands through air is often difficult. Adjust the position of the deck unit transducer and try the RELEASE command again until an acceptable position is found.

NOTE: If the measured voltage is negative, then the voltmeter leads are reversed. Confirm that a positive voltage is sent to the burn wire module (the anode) upon receipt of a RELEASE command prior to deploying the unit.

After the TR-7000 receives a RELEASE command, verify that it responds with four pings, 3.2 seconds apart.

4.3 Rigging

Before deployment, be sure that the dissolving wire module and the ground screw are properly installed and securely tightened. The disposable ballast should weigh between 75 and 100 pounds in seawater and be attached to the release base with the Benthos provided ¼ inch stainless steel shackle. Insure that additional hardware will not cause jamming of the release mechanism.

4.4 Deployment

The most important thing to remember during deployment is to attach the TR-7000 to the mooring or weight in such a way that the transducer will be pointing towards the surface. The acoustic path should be free from obstructions for the best possible results.

Be certain that the tether between the transponder and the anchor is at least long enough to allow for TR-7000 overshoot when the anchor hits the bottom.

Before deployment, be sure the following has been done:

- Inspection for damage
- Battery voltage tested and battery changed if necessary
- Functional test complete.

The unit may now be attached to the mooring assembly to be deployed. The mooring assembly should have been designed with the following considerations:

- Have a long enough tether between the TR-7000 and the anchor to avoid damage due to overshoot when the anchor hits the bottom.

- Provide a clear acoustic path to the surface from the transducer of the TR-7000.

The length between the anchor and transponder should be long enough to provide a clear acoustic path, and short enough to minimize the watch circle errors, or 4 to 10 feet. However, this figure will vary dependent upon bottom relief and individual applications.

WARNING: Be sure that the TR-7000 is switched ON before deploying by removing the magnet.

After the TR-7000, with its instrumentation and mooring packages is deployed, the deck unit can be put into RANGING MODE Repetitive STOP/START ENABLED. (Please refer to the DS-7000 manual for a detailed discussion of this feature.) Now a constant update of SLANT RANGE will be maintained until the maximum range is reached.

NOTE: The TR-7000 will stop replying at the end of the programmed enable time or if it is programmed to recognize a DISABLE command and such a command is sent. See Section 7.3.1 for further details.

4.5 Operation

To interrogate a TR-7000 Transponder, first set the TRANSMIT FREQUENCY SELECT switch of the deck unit to the receive frequency of the transponder you wish to command. Send a single transpond from the deck unit and the TR-7000 Transponder will reply with a single ping.

4.6 Recovery

To send the RELEASE command, again make sure the TRANSMIT FREQUENCY SELECT switch is set to the receive frequency of the transponder you wish to command. The RELEASE command, or options, and their corresponding codes (A,B,C,D,E,F,G,H) are clearly indicated on the TR-7000 hardhat label. Set the COMMAND SELECT switch to the proper letter code, as indicated by the label, and send the command transmission. The TR-7000 will respond with four pings, 3.2 seconds apart, after the command has been properly received. These will show up on the display and may also be heard on headphones, if available. To verify that the release wire is, in fact, dissolving, send a single interrogate ping to the transponder. The TR-7000 will respond with four (4) pings, 3.2 seconds apart while the current is flowing through the dissolving wire electrode circuit. The first reply may be used to obtain slant range to the instrument. Repeat the process periodically to verify that the wire is still dissolving and to check slant range. A normal period of time for release is 5 to 10 minutes for the wire loop to break through; however, the wire loop ends will continue to dissolve until the wire strands are dissolved inside the jacket of the original wire loop. This process will take an additional 5 to 10 minutes during the ascent of the transponder. Once the wire dissolution circuit has shut down, the transponder will revert back to replying with one ping when interrogated. It will float transducer-down when on the surface for acoustic relocation.

There are two handles molded into the hardhat opposite each other on the hardhat flange which can be used for grappling to aid in recovery.

Retest the unit after recovery to verify that the battery voltage is still adequate, then insert the on/off magnet back into the hose clamp bracket.

4.7 Options

Along with transmit and receive frequencies, all options are specified on the TR-7000 label and defined in the following sections. Any option parameter not specified on the label may be assumed to have been shipped with the following standard parameters.

4.7.1 Receiver Lockout Time

This is the amount of time that the receiver is inhibited after receiving a pulse of the correct frequency. This helps prevent undesirable multiple interrogations which would result from multipath phenomena, thus saving battery energy. The standard lockout time is 1.5 seconds, although .5 second to 127.5 seconds (nearest .5 sec) is available as an option. (Programmable via RS-232)

4.7.2 Transmit Pulse Length

This is the duration of the transmit frequency burst. The standard pulse length is 10 milliseconds, and this is the proper pulse length when using Benthos deck units. However, other manufacturers' deck units may require different pulse lengths. Therefore, as an option, any pulse length from 10 to 26.5 milliseconds may be specified at time of order. (Programmable via RS-232.)

4.7.3 Turnaround Delay

This is the time delay between reception and transmission. It is a constant delay which should be subtracted from the measured travel time in order to obtain the most accurate slant range. In the standard unit this delay is 10 milliseconds; however, any delay between 10 and 53.12 milliseconds (programmable via RS-232 command) may be requested as an option when ordering the TR-7000.

4.7.4 Command Options

4.7.4.1 Command Configurations

The standard command on the TR-7000 is the RELEASE command. The following two acoustic command options are available as options from Benthos for the TR-7000:

1. ENABLE/TIMED DISABLE
2. ON-OFF

A TR-7000 Transponder, which is equipped with one or both of these functions will respond to an acoustic command from the surface to perform the corresponding operation. The command codes are unique to Benthos instruments and may only be transmitted by the following Benthos deck units:

1. Model 210-TDU Transponder Deck Unit (10-15 kHz)
2. Model 210-ADU Command Code Generator (7-15 kHz)
3. Model 455 Acoustic Signal Processor (7-15 kHz)
4. Model DS-7000 Transponder Deck Unit (7-16 kHz)

Eight discrete codes (A,B,C,D,E,F,G and H) may be generated for each specific frequency.

The command option selected and corresponding code (A,B,C,D,E,F,G or H) will be displayed on the TR-7000 label.

4.7.4.2 Command Enable/Timed Disable Option

In some instances it may be desirable to have the transmitter portion of the TR-7000 enabled for a relatively short period of time. For example, one user may wish to maximize the battery life of the transponder by eliminating the possibility of unnecessary transponds while the transponder is not being used. Another user may want the TR-7000 to remain quiet for a period of time so that it will not interfere with another acoustic instrument in the area. For whatever reason, this Command Enable/Timed Disable option is the simplest solution.

A TR-7000 with a Command Enable/Timed Disable Option will operate as follows:

1. The TR-7000 will power-up in the "Enabled" state; that is, it will reply when it receives the proper frequency.

2. It will then remain "Enabled" for the selected time (see ENABLE TIME following). This will usually be enough time to deploy and track the descent.

3. Once the Enable time runs out, the TR-7000 will no longer reply when it is interrogated until an ENABLE Command is received.

4. Whenever an ENABLE command is received, the transmitter is "Enabled" and will remain so for the Enable time.

5. To verify that an ENABLE command was executed, simply send a single transpond and listen for the proper reply.

6. If, for whatever reason, the TR-7000 is not "enabled" when a RELEASE command is received, release will occur and the unit will automatically "enable" itself so that its ascent may be tracked.

ENABLE TIME: Selected at the time of order, and indicated on the TR-7000 label. Enable time is set for 12 hours (±.1% as a default by the factory unless otherwise specified.) Enable time can be programmed from 1-99 minutes, hours, or days by RS-232 command.

4.7.4.3 Command On/Off Option

The Command On/Off Option performs the same function as the Command Enable Option. However, the On/Off Option gives the user more control, at the expense of using up one more command code. Rather than a timer, the On/Off Option uses a different command code to disable the transmitter portion of the TR-7000.

A TR-7000, with the Command On/Off Option, will operate as follows:

1. The TR-7000 will power-up in the "Enabled" state; that is, it will reply when it receives the proper frequency.

2. It will remain "Enabled" indefinitely, or until an "OFF" command is received.

3. After an "OFF" command has been received, the TR-7000 will be in the "Disabled" state and will not reply at all to interrogation pings. It will remain "Disabled" indefinitely, or until an "ON" command is received.

4. The On/Off process may be repeated as many times as is desired.

5. Release can occur in either state. In the "Disabled" state, the unit will reply with the regular four acknowledgment "pings", but will not reply to subsequent interrogation "pings". In the "ON" state, the unit will reply with four acknowledgment "pings" plus respond to any subsequent interrogation "pings".

4.8 Preparation for Redeployment

4.8.1 The Re-arming Kit

In order to redeploy the TR-7000, the transponder should be re-armed with a new dissolving wire module and an expendable link. The Benthos Expendable Re-arming Kit (A-210-226) includes three (3) ¼ inch stainless steel shackles and three (3) expendable dissolving wire modules.

4.8.2 Replacing the Dissolving Wire

The old dissolving wire module should be unplugged from the single pin connector and unscrewed from the release base. A new shackle should be installed on the lever arm and a new dissolving wire module should be installed in the release base. These should be saved and returned to Benthos for remolding of new modules. The Delrin tip of the release lever should be inserted into the dissolving wire loop. Insure that the wire loop is installed in the necked down section of the delrin tip. Both the expendable dissolving wire module and the ground screw should be tightened and checked for integrity prior to redeployment.

4.8.3 Replacing the Ground Wire

NOTE: Depending on the deployment environment and amount of use, it is possible that the ground wire (the cathode) may become brittle in time and some of the strands of wire will break at the junction of the wire and the ground screw. Prior to deployment, the ground wire should be lightly flexed and checked for broken strands.

When broken strands are observed, loosen the ground screw, remove the wire from the screw, cut off approximately one inch of wire, re-strip the insulation to expose approximately ½ inch of wire strands and reinsert back into the hole in the ground screw. Make sure that the ground wire is firmly clamped by the large washers of the ground screw assembly.

4.8.4 Redeployment

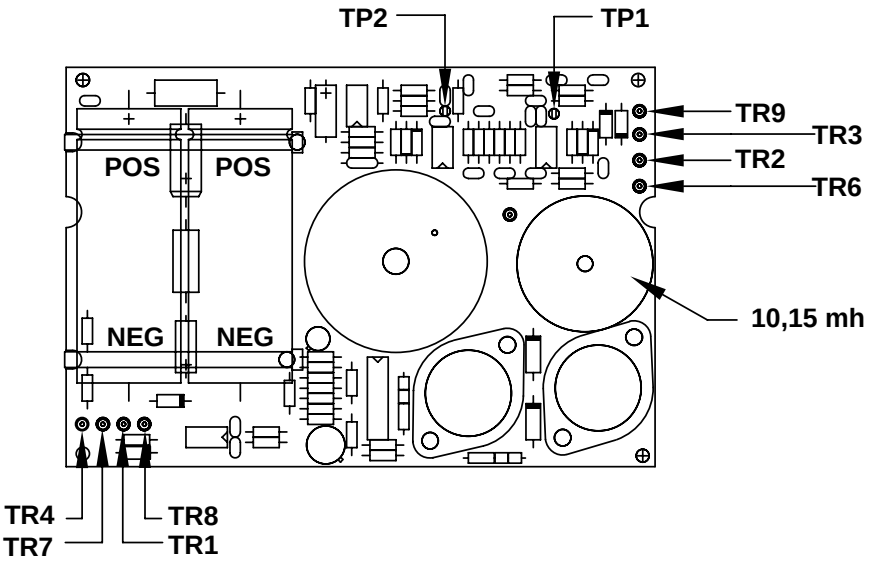
Once the transponder has been re-armed, follow the normal deployment procedures described in the beginning of Section 4.

5.0 HARDWARE DESCRIPTION

5.1 Electronics Chassis Assembly (Part No. B-600-5) (see Figure 5-1)

This modular assembly includes 7000 series circuit boards, the power interface board, and the mounting plate. When installed, a connector on the power interface board mates with a connector on the battery assembly, and a connector on the power interface board mates with a connector on the magnetic switch assembly. Both connectors are polarized to prevent incorrect insertions. The transducer wires are connected to TR2, TR3, and TR9 on the Driver/Preamp Board.

The three circuit boards are installed back to back with a common connector in between.



Driver/Preamp Board Top View

Figure 5-1

5.2 TR-7000 Driver/Preamp Board (Part No. C-600-4)

This board contains all the large components required for transmitting, i.e. output transformer, inductor, power transistors and capacitors. It also contains the circuitry for transmit pulse gating, and the sensitive receiver preamplifier. All wires connecting the electronic package to the transducer and power interface board are connected to this board.

To remove the Driver/Preamp board, power OFF and desolder all wires from the turret terminals, then remove the four corner screws and unplug the board (see Figure 5-1).

Other functions on the Driver/Preamp board are:

- 9.2V Voltage Regulator
- 5V switching Regulator

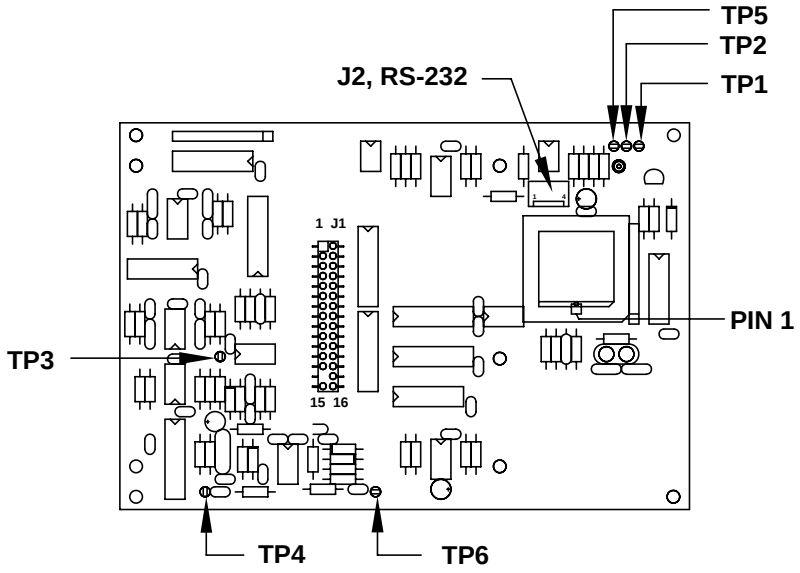
5.3 TR-7000 CPU Board (Part No. C-600-3)

The CPU board contains the remaining receiver circuitry including the last stage of the preamp, the limiter amplifier, hardware detector, and enough hardware to allow software implementation of a second, simultaneous detection of a second tone.

Other functions on the CPU board are:

- ENABLE timer
- 16 Khz signal injection (sensitivity control)
- RS-232 interface.

To remove the CPU board, power off and then remove the four corner screws and unplug the board. The synthesizer board is mounted to the CPU board and it will come off too. If the Synthesizer board is removed first (see Section 5.4), the CPU board will come off easier (see Figure 5-2).



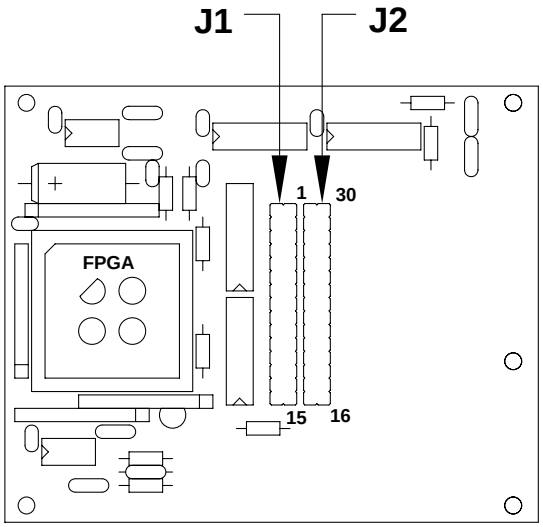
CPU Board Top View

Figure 5-2

5.4 TR-7000 Synthesizer Board (Part No. C-600-5)

The Synthesizer board uses a FPGA to do a direct digital synthesis of two tones, including the Real and quadrature phase of each. The synthesizers are each capable of resolving tones to 16Hz. The CPU board can reprogram the frequencies on the fly with no settling time required.

The Synthesizer board is mounted to the CPU board. To remove the Synthesizer board requires removing four screws which hold the board to four spacers (see Figure 5-3).

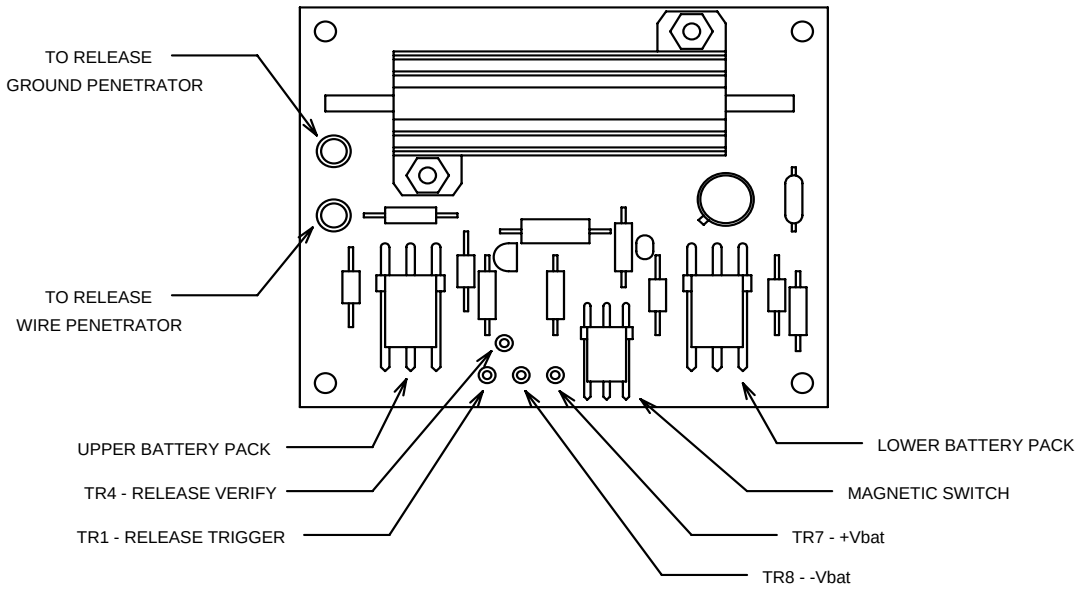


Synthesizer Board Top View

Figure 5-3

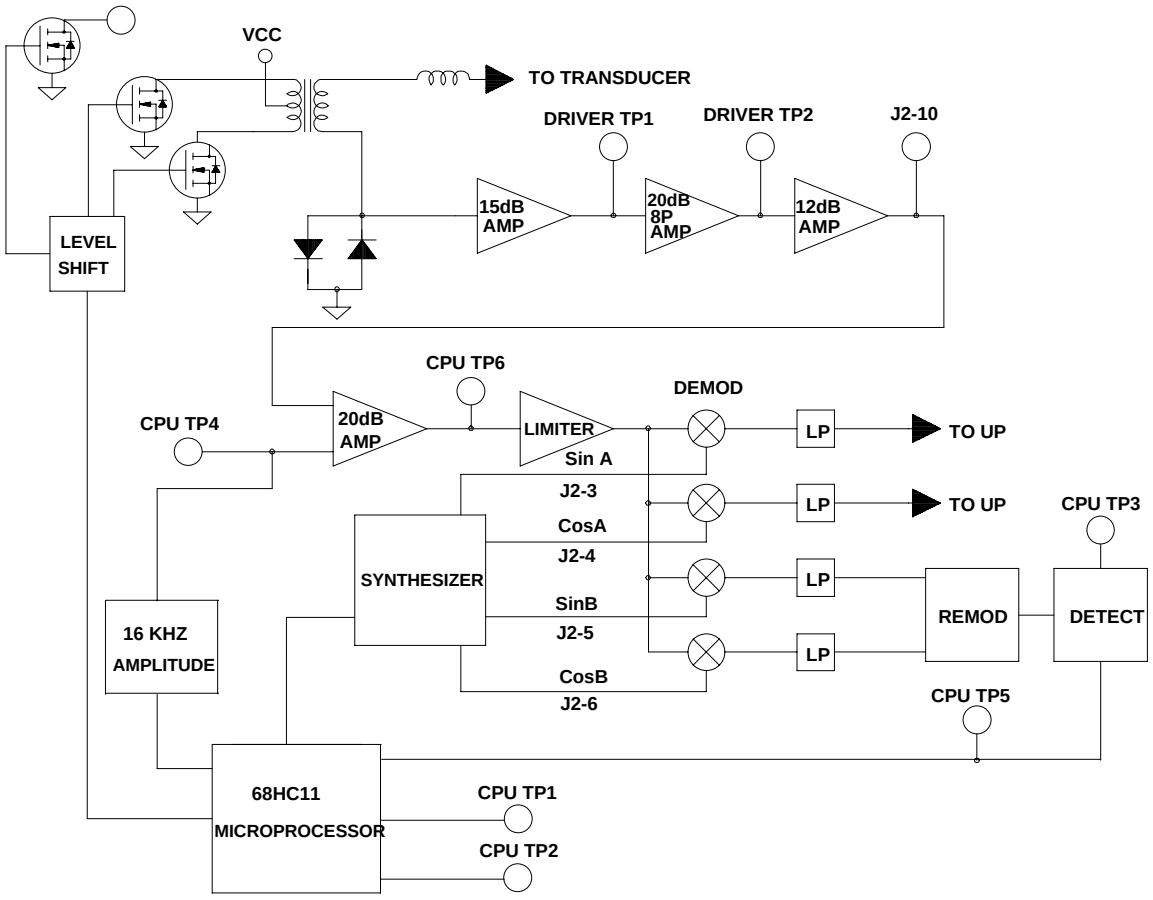
5.5 TR-7000 Burn Wire Release Interface Board

Upon receipt of the proper command code for RELEASE, a silicon controlled rectifier is latched on. The SCR allows current to flow through the dissolving wire to the release ground. Also, a four-ping acknowledgment is sent automatically. The SCR remains on until the wire is completely dissolved. As long as the SCR is on, the TR-7000 will reply with five pings when interrogated.



TR-7000 Burn Wire Release Interface Board, Top View

Figure 5-4



Circuit Flow Diagram for TR-7000 Transponder

Figure 5-5

6.0 THEORY OF OPERATION

6.1 General

The TR-7000 is an acoustic transponder which can be recovered by activating an electrochemical release that trips a mechanical linkage. The following sections describe the details of the acoustic, electrochemical and mechanical operation of the transponder.

6.2 Command Release

Upon receipt of the proper command code for RELEASE, a silicon controlled rectifier is latched on. The SCR allows current to flow through the dissolving wire to the release ground. Also, a four-ping acknowledgment is sent automatically. The SCR remains on until the wire is completely dissolved. As long as the SCR is on, the TR-7000 will reply with five pings when interrogated.

6.3 Electrical and Mechanical

The dissolving wire loop that is used to support the release lever tip will break and trip the lever when it receives a proper signal from the TR-7000. The method in which the wire loop breaks is electrochemically driven, where the wire loop is the anode, the ground screw is the cathode, and the water between them is the electrolyte. During non-releasing deployed periods of time, the wires from the electrodes are not connected to each other or any other metallic objects in seawater. The release command closes a switch which places 26 volts across the electrodes with the wire loop positive (the anode).

The 26 volt potential will polarize the electrodes, such that metallic dissolution occurs at the anode and hydrogen reduction or calcium carbonate deposition occurs at the cathode. The initial battery current drain is approximately 2.0 amps. These reactions will slow down as the surface area of the anode (the wire loop) becomes smaller.

After approximately 6 to 10 minutes, the wire loop will break through and trip the lever tip, which in turn releases the shackle and anchor weight. As the TR-7000 floats to the surface, the metallic dissolution reaction will continue until the wire loop strand ends have dissolved away outside the insulation jacket and worked their way up inside the jacket by approximately 1/8 inch. When the reactions occur at a rate such that the battery current drain is less than approximately 30 milliamps, the SCR will switch off the battery power to the dissolving wire loop and the TR-7000 will respond with single pings again when interrogated.

6.4 Receiver

The receiver consists of five basic blocks:

1. Transducer
2. Preamplifier
3. Sensitivity Control
4. Limiter-amplifier
5. Detector.

The transducer converts the acoustic energy into an electrical signal. At long ranges, this signal may be very small, approximately 10 μvp-p mixed with noise. The preamplifier is a very low noise amplifier which provides approximately 62 db of gain and band shaping. The limiter amplifier will operate on signals as small as 10 mvp-p.

At the beginning of the last 20db gain section, provision is made for injecting 16 Khz of variable amplitude. This signal, which is considered out-of-band, serves to limit the sensitivity of the detector. At close range this reduces false alarms and provides a clean detector threshold. The injected value is controlled by a software feedback loop. During sleep intervals the injected value is reduced to zero to make sure the detector hears the receive tone.

After limiting, the signal plus noise is fed into a frequency detector which consists of two XOR circuits which modulate the incoming signal with the frequency to be detected. A two pole, 100 Hz filter limits the band of accepted signals. After filtering, the real and quadrature components are recombined by remodulating them both to 16 Khz and then summing them through an AC-coupled summing amplifier. The envelope is then diode-detected and fed to a comparator. The comparator interrupts the microprocessor, which also stores the time of the interrupt to avoid jitter due to variations in interrupt latency.

There is a second hardware path which ends with the demodulators. Built-in A/D converters read the real and quadrature outputs of these signals as well as the first set previously described. Software uses these signals (total of four) to detect and qualify up to two tones at a time.

6.5 Synthesizer

The synthesizer is a Xilinx XC3020 Field-Programmable Gate Array (FPGA) with a small amount of associated circuitry. This FPGA implements two independent synthesizers, including real and quadrature phases for each. The method used is the phase accumulator technique. A 12 bit number is added to a 12 bit accumulator at a constant 128 Khz rate. By inverting the accumulated number whenever it goes over half-scale, a triangle wave is synthesized. A separate full adder adds 90º (128 counts) to the accumulator to the generate the quadrature signal. The top eight bits are used to form an analog waveform which is converted to logic levels using a comparator. Four D/A converters and four comparators are required to obtain the two frequencies with quadrature phases required.

The benefits of this method are the frequency agility and resolution obtainable. The FPGA is used because chip implementations of this method require too much current for a circuit which must be on continuously, even when the microprocessor is asleep. (One of the synthesizers is turned off during sleep, but one is still required to receive the wakeup/Receive tone).

6.6 Controller

The microprocessor is responsible for implementing the setup stored in memory. It sets the Synthesizer for the desired Receive and Transmit frequencies, qualifies incoming tones before accepting them, detects A-H commands and assigns the proper service routines, operates the Enable timer, and sets the incoming sensitivity. It also recognizes a new form of command structure and will respond to a wide range of new commands based on that structure.

The qualification process reduces false alarms by forcing a tone detected first by hardware to meet a set of extra requirements. First, the tone must stay above a fixed threshold for at least 3.5ms (8 samples). Second, it must have less than a maximum Doppler phase shift of 150º over that time period. The Doppler requirement filters out tones greater than 120 Hz away from the receive tone and provides extra protection against high amplitude out-of-band tones bleeding through the detector. A third requirement imposes a maximum variance on the individual phase shifts measured between samples.

6.7 Transmitter

The transmitter consists of three basic blocks:

1. Transmit frequency synthesizer, which can also be a receive frequency synthesizer
2. Pulse control
3. Level shifting and Power amplifier.

The microprocessor decides when to transmit, for how long, and at what frequency, based on setup parameters stored in nonvolatile memory. There are two synthesizers for the microprocessor to choose from, and either can be programmed with virtually no time constant delay. Although not currently used, the FPGA circuit allows two frequencies to be transmitted simultaneously to create a dual tone output.

The gated output frequency is applied to the output amplifier in the form of two logic signals with a small guardband (1us) separating their ON states. A level shifter converts them to the level of the battery voltage. The power amplifier consists of two power MOSFET transistors operating on opposite sides of a tapped primary transformer. The transformer and tuning inductor combine to deliver up to 3000 volts across the plates of the transducer element. The same transducer element is used for both transmit and receive.

6.8 Command Theory, A-H Commands - Benthos FSK Emulation

The Benthos FSK acoustic command consists of two separate frequencies alternating at a specific shift rate. One frequency, called the "in-band" frequency, is set to the RECEIVE frequency of the transponder. The other frequency, called the "out-of-band" frequency, is arbitrarily fixed at 12.5 Khz or 18.0 Khz, which are otherwise unused frequencies. The detector in the underwater transponder will respond "true" for the in-band frequency and "false" for the out-of-band frequency. Its output, therefore, will be a square wave whose frequency is the shift rate of the command. The command receive circuit then checks for a specific frequency of this square wave and, if it is correct for 50 complete repetitions, the appropriate function will be executed.

There are eight possible shift rates and they are determined by the letter part of the code. The shift rates are:

A:	82.5 Hz	E:	71.9 Hz
B:	110.9 Hz	F:	77.0 Hz
C:	136.5 Hz	G:	118.8 Hz
D:	100.0 Hz	H:	127.3 Hz

Shift rates are detected in software by using an exponential filter on the computed input amplitude to establish a floating baseline for the input signal. This acts like a highpass filter to eliminate DC components. Repetitions of the shift rate are counted by noting the transitions from a period of "greater" amplitude samples after a period of "lesser" amplitude samples. The period also has min/max values imposed on it to provide greater security against random noise.

6.9 Command Enable/Timed Disable Feature

The ENABLE feature prevents unwanted transmissions from occurring due to unauthorized transponding, other sonar equipment, or random interference. Whatever the source, the result could be a large number of unnecessary transponds by the TR-7000 which could result in premature battery drain.

Basically it works as follows:

The TR-7000 powers up in the ENABLED state; that is, it will reply when it receives the proper frequency. It will then remain ENABLED for the selected time. This will usually be enough time to deploy the unit and range on it (if desired). If not, the user may simply send it an "ENABLE" command to extend the enable time. Once the enable time runs out, the transmitter portion of the TR-7000 is disabled **UNTIL** an ENABLE command is received.

The default ENABLE time is 12 hours. It can be programmed from 1 minute to 99 days. Use of days is not recommended since it defeats the purpose of the timer.

6.10 Command Theory, M-FSK Command Set

The M-FSK Command set is recommended for applications which must operate in a very high multipath environment, or when a two way dialog between the TR-7000 and the surface is desirable. This new method of sending and receiving commands and data requires an upgrade to the DS-7000 deck unit. Command transmission requires a software upgrade. Command reception (data) requires a command receiver card which plugs into a card slot normally occupied by a standard receiver card. Contact Benthos for information on these upgrades.

The new technique is significantly different than standard FSK encoding. In standard FSK, one tone is assigned the value "1" and a second tone is assigned the value "0" throughout the length of the message. In this new method tones are dynamically assigned the value "1" or "0". The assignments must change after every bit transmitted because the tone sent is retired after being used once to avoid confusion when it reappears due to multipath interference. Therefore, a 16 bit message requires 16 tones out of a set of 17 tones. Furthermore, each message is preceded by an Alert tone, which is a fixed 18th tone. The tone list for the lower band implementation follows.

Alert:	8.75 Khz	9:	11.00 Khz	
1:	9.00 Khz	10:	11.25 Khz	
2:	9.25 Khz	11:	11.50 Khz	
3:	9.50 Khz	12:	11.75 Khz	
4:	9.75 Khz	13:	12.00 Khz	
5:	10.00 Khz	14:	12.25 Khz	
6:	10.25 Khz	15:	12.75 Khz	(skip 12.50 Khz)
7:	10.50 Khz	16:	13.00 Khz	
8:	10.75 Khz	17:	13.25 Khz	

12.5 Khz is skipped because it is used as the out-of-band tone in Rate-Coded commands.

The message format is given below:

ANNNNNNMMDDDDDDDD
where A = Alert tone
NNNNNN = ID#
000000= Global ID
1-63 = specific ID
MM = Type of message
00 =MSB
01 =LSB
10 =Extra LSB
11 =Command
DDDDDDDD =Data or Command

There is 64ms between bit frames. Each command word requires 1.0 seconds to transmit. There is always at least 500ms between Commands. No error coding is included because the setup for every bit depends on the bit previously received. Once a bit is missed the microprocessor aborts the acquisition process.

The algorithm make every effort to get each bit correctly. Two detectors are used, one for each possible tone. The peak average amplitude of each tone is calculated and stored in case both tones are present and a tie-breaker is required.

A list of FSK commands is given below. This list is included for informational purposes only. Many of these commands will become transparent to the user since the DS-7000 will have its own command protocol superimposed on the actual acoustic command protocol.

Xmit0	Retransmit Data Byte 0 previously received
Xmit01	Retransmit Data Byte 0 And 1 previously received
Xmit_Bat	Xmit Battery Voltage As decimal value XX.X volts
Xmit_Qtime	Transmit Total On Time In Months/Days
Xmit_Atime	Awake Time: Use 4 Bit Exponent, 8 Bit Mantissa
Xmit_Pingct	Total Ping Count: Use 4 Bit Exponent, 8 Bit Mantissa
Xmit_Payload	Send 2 Bytes Supplied By Payload (Special, Contact Benthos Marketing)
Store_Rec	2 Byte Receive Freq Code
Store_Xmit	2 Byte Transmit Freq Code
Store_Abcd	2 Byte Benthos Command Assignment
Store_Efgh	2 Byte Benthos Command Assignment
Store_Id	Id Only
Store_Ping	Length in ms.
Store_Ta	Turnaround time in ms.
Store_Miss	Miss_Interval
Store_Period	Missing Ping Period in seconds
Store_Inhib	Inhib Time in seconds
Store_Data0	Store Data Byte 0
Store_Data1	Store Data Byte 1
Store_Hr_Min	Units used for Pingenable (D, H, or M)
Store_Pingen	2 BCD Digits Representing Pingenable Time
Store_Smartr	2 Byte Receive Tone For Master/Slave Operation
Store_Smartx	2 Byte Xmit Tone For Master/Slave Operation
Store_Noise	Also Enables It
Disable_Noise	Disable
Start_Miss	Start Missing Ping Option
Tr_On	Ping-Enable On
Tr_Off	Ping-Enable Off, Miss_Ping Off
Set_Master	Do Time-Of-Flight 4 Times using substitute (Smart) set of tones
Set_Slave	Use Second (Smart) set of tones
Clr_Ms	Go Back To Normal Mode from Smart mode
Set_Sleep	Go To Sleep

7.0 Changing the Setup Parameters

The setup parameters can be changed by the user if some care is exercised. **The most important thing to remember is to record the new setup parameters and note them on the unit and on a separate document.**

PROCEDURE

a. Turn the TR-7000 OFF by taping the magnet over the magnetic switch.

b. Open the glass housing as outlined in section 3.0.

c. In order to get the maximum power out of the TR-7000, be sure that the proper inductor is installed for your desired transmit frequency.

Transmit Frequency Range	Inductor	
	Inductance	Benthos Part Number
7.5 - 12.5 Khz	15 mh	0553-001-5
13.0 - 17.25 Khz	10 mh	0553-001-2

See Figure 5-2 for inductor location. To change the inductor, remove the Driver/Preamp board and carefully replace the inductor. In most cases, however, you should be able to choose a new frequency in the frequency range of the existing inductor. Note that the Receive frequency is not significantly effected by the choice of inductor. In fact, the M-FSK series of command codes utilize frequencies from 8.75 Khz through 13.25 Khz.

d. Find the four pin connector on the CPU board and plug in the RS-232 cable supplied with the spare parts kit. See Figure 5-3 for the exact location of the connector. The four pin connector is polarized by a shelf on one side to avoid confusion. Connect the "D" connector to the serial port of a personal computer. The shell of the connector contains a voltage inverter to supply -5 volts as well as the positive battery voltage. RS-232 communication requires at least ±3 volts for two-way communication. The standard interface will work with most any communications program, including PROCOMM, BITCOM, MIRROR, Microsoft WINDOWS TERMINAL, etc. The Communications setup required is 9600 baud, 8 bits, one Stop bit, and No Parity.

e. There are many commands available. A full list is given in the Appendix. Only eight will be covered here. They are:

RX	Receive frequency
TX	Transmit frequency
BA-BH	Benthos A-H assignment
PE	Set Enable timeout (1-99)
CK	Set units ((M)inutes, (H)ours, (D)ays)
SAVE	Store in nonvolatile memory
DEFAULT	Restore default values to RAM

f. Typing RX followed by a carriage return will return the present receive frequency in Khz. If an argument is included after RX, such as "RX13.221", the unit will attempt to program the receive frequency with the closest legal value to the number entered. Entries can have up to three digits after the decimal point. Entering RX↵ again will display the value actually entered, based on the 16 Hz resolution of the synthesizer. To maintain compatibility with the DS-7000, only multiples of 250 Hz should be used. Values within 200 Hz of 8.75 Khz, 12.50 Khz 16.00 Khz, and 18.0 Khz will be rejected as illegal since these have special meanings for the TR-7000.

g. To store permanently in EEPROM, the SAVE command is used.

> **NOTE:** Until the SAVE command is used, changes are stored in RAM and will be lost if the unit is turned off and then repowered.

h. In a similar manner, the Transmit frequency can be recalled and modified using the "TX" command. The same list of prohibited frequencies apply.

i. The BA through BH commands assign service routines to the letters A through H. The choices are listed below. Use the first letter only.

(N)ULL	Designate unused command
(E)NABLE	
(D)ISABLE	(Disable Ping and Missed Ping)
(R)ELEASE	N/A
(S)ETBIT	(Contact Benthos for applications)
(C)LEARBIT	(Contact Benthos for applications)
(M)ISSED PING	
(O) DEMO	(M-FSK demo)

For example, typing BA↵ will return one of the eight letters: N, E, D, R, S, C, M, or O. Typing BE E will assign the ENABLE command to command E. Typing BHN will remove any command assignment from H.

The following syntax examples are all valid:

BHN
BH N
BH=N

NOTE: All commands A-H must be given some assignment, if only (N)ULL, to clear out previously programmed assignments.

j. The timeout period can be viewed or set using the PE command. Legal values are 1-99. The HM command sets the units:

M=minutes
H=hours
D=days

Hours (H) is the default unit.

k. The DEFAULT command restores the default settings to RAM. To permanently restore settings, the SAVE command is required as well.

l. After making the changes, connect the transducer to the chassis. Remove the magnet and listen for four power-up pings. **BE CAREFUL!** There will be dangerous voltages in the vicinity of the transformer and inductor on the Driver/Preamp board.

m. You may now wish to check the receive frequency by attaching a frequency counter to pin 5 on the J2 test connector. You should see the selected frequency present continuously. The ground lead of the counter may be attached any place on the chassis. The negative side of the big blue 22,000uf capacitors on the Driver/Preamp is also a good choice.

n. Power OFF, by taping the magnet over the magnetic switch. Remove the RS-232 cable by flexing the engaging lock on the connector as the cable is withdrawn.

o. Close the glass housing, refer to Section 6.0.

p. Perform a system test, as described in Section 4.2.

IMPORTANT: Be sure to clearly mark the changes on the housing and note the change in your records!

8.0 MAINTENANCE

There is essentially no maintenance required on the TR-7000. Simply remove the magnet, attach a weight, and toss it overboard.

It is recommended that no attempt be made to open the TR-7000 housing without first consulting Benthos.

8.1 Opening the Glass Housing

The following list details the steps required to open the glass housing of the TR-7000.

a. Materials needed:

- heat gun
- 18-inch diameter hose clamp
- small roller
- Butyl sealant strip (Benthos Part #0900-024)
- wide black tape (Benthos Part #0903-0l3)

b. Remove the hardhat assembly.

c. Remove the hose clamp assembly.

d. Place the transponder in some sort of a cup to prevent it from rolling.

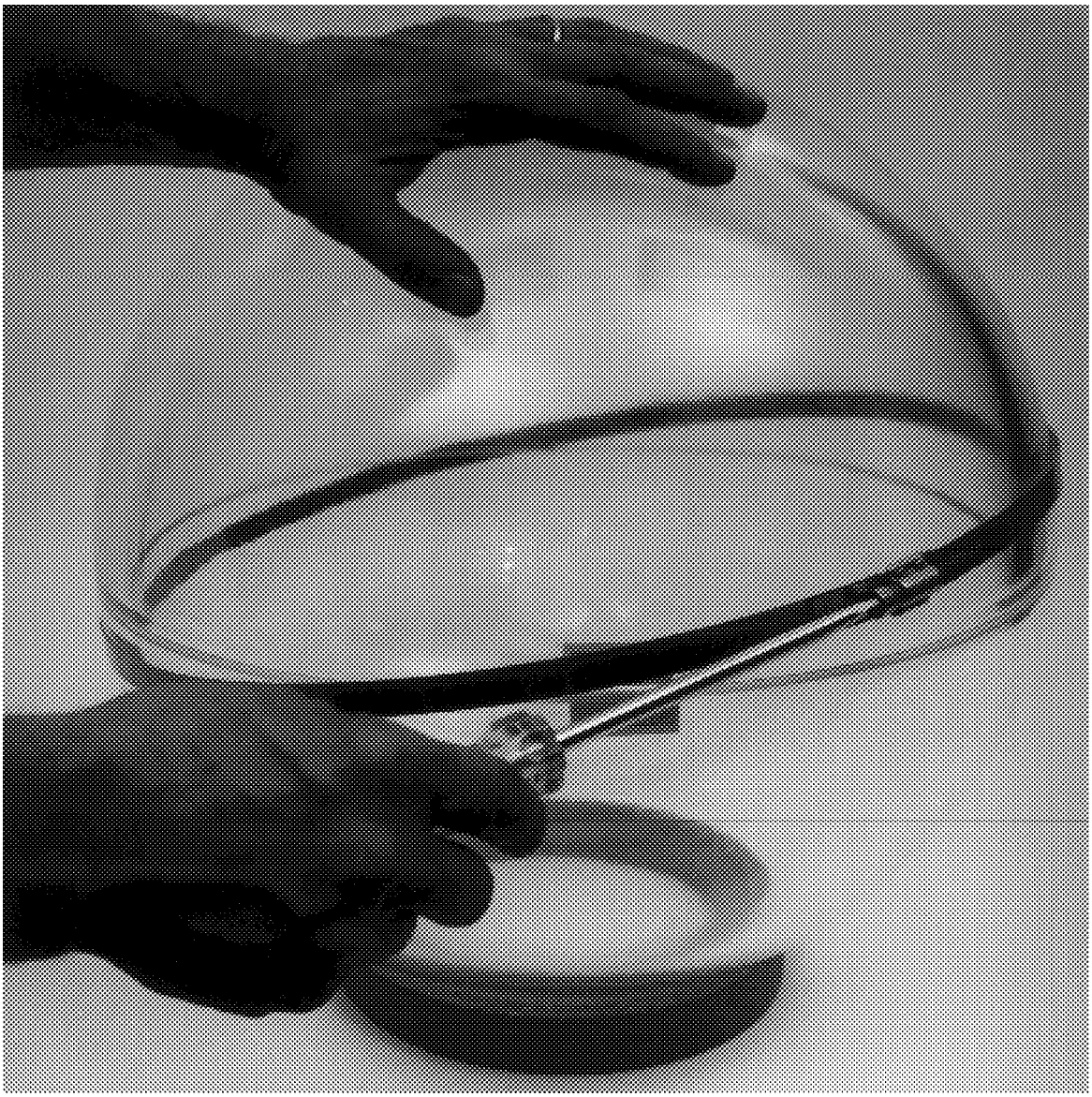
e. Turn the unit off by taping the supplied magnet over the "match arrow" mark near the equator on the lower hemisphere. Wait approximately two minutes for the capacitor to discharge, then test the transponder with a deck unit to be sure that it is, in fact, off.

f. The two hemispheres are held together by the tape around the equator and by about four inches of vacuum. Carefully remove all tape and sealant from the equator. The vacuum inside should still hold the halves together.

g. The best way to separate the halves is to slowly tighten a hose clamp diagonally across the equator, as shown in Figure 8-1. Often it is possible to tap them apart using the palm of your hand, but in either case you must be very careful not to chip the precision ground surfaces at the equator. Even small chips can ruin the pressure integrity of the housing.

h. Now remove the upper hemisphere and place it upside down next to the lower half. The transducer makes a convenient stand for this half.

i. **BE CAREFUL!** If the unit is powered on, there may be potentially harmful high voltage on the board, particularly in the area of the transducer terminals.



Separating the Glass Hemispheres

Figure 8-1

8.2 Changing the Battery Pack

The battery life of the TR-7000 is very long, depending on its use, so rarely will this step be necessary; but if so, it is not difficult to change the battery pack. Replacement battery packs may be ordered from Benthos. Please specify Benthos Part No. C-210-301 when ordering.

PROCEDURE:

a. Open the glass housing by following the steps in Section 8.1.

b. Remove the magnet and wrap it with electrical tape. Place it on the P.C. board, directly above the magnetic switch, and stick it down with another piece of tape.

c. Wait two or three minutes for the capacitor to fully discharge.

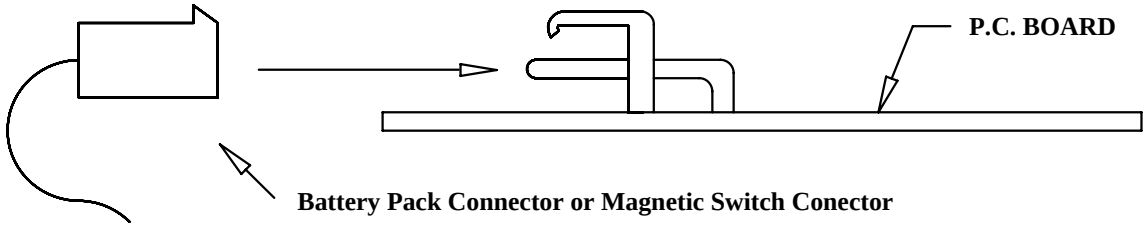
d. Now you will be able to remove the printed circuit board without it powering on in your hands!

e. Remove the 1/3-20 nut and washers in the center of the board. Now lift out the circuit board and the battery packs.

f. Unplug the old packs and discard them.

g. Set the new battery packs in the hemisphere. Dry out or replace the desiccant packs if they are pink in color.

h. Plug in the P.C. board (see Figure 8-2), with the magnet still over the magnetic switch, and replace it over the batteries. Apply a little glue to the battery spacer if required. Replace the nylon washer, flat washer, lock washer and nut in that order. Tighten just until the board begins to bow slightly. Do not over tighten.



Proper Connector Orientation

Figure 8-2

i. Remove the magnet and listen for the power-up ping after about three seconds.

j. Close the glass housing following the instructions in Section 8.3.

8.3 Closing the Glass Housing

a. **Important**: Close the sphere in as "dry" a room as possible, preferably an air conditioned area. Avoid closing in a hot, humid environment, because in the low temperature deep ocean, much of this moisture will condense and may cause serious electrical problems.

b. Very thoroughly clean off the precision ground mating surfaces of both hemispheres. Use a non-residue forming industrial solvent, such as Trichlorethelene or tolulene. **CLEANLINESS IS VITAL!**

c. Align the match arrows and gently place the two hemispheres together.

d. Slide the hemispheres slightly apart so that there is a gap. Using a hair dryer or a heat gun, blow hot air into the sphere for about 15 seconds.

e. Immediately slide the halves back together, keeping the match arrows lined up. You will notice a considerable vacuum force now holding the halves together.

f. Gently tap the halves in place with the palm of your hand in such a way as to get the best possible "match" at the equator. That is, with the match arrows lined up, try to minimize the overhangs at the equator.

g. Now thoroughly clean the outside of the equator area using a solvent. Again, **CLEANLINESS IS VITAL!**

h. Wrap the soft butyl sealant strip (Benthos Part No. 0900-024) around the joint at the equator, keeping the paper on the outside. Carefully cut the strip so the ends butt together. Do not overlap the ends.

i. Still keeping the paper on, roll the sealant strip so that it flattens out to approximately double its width at starting. This may be done with a small roller. Be careful that the two halves do not slide during this operation.

j. After rolling, make certain that the strip is still centered on the glass joint and the sealant has fused together at the ends.

k. Remove the paper from the sealant strip.

l. Apply three complete turns of the wide black tape (Benthos Part No. 0903-013), centering the tape on the sealant strip. Stretch the tape as it is being wrapped so that it conforms to the curvature of the glass. Rub the tape smooth using hand pressure.

m. Replace the hose clamp assembly, centering the ring around the transducer. Carefully tighten the adjustment screws. Do not over tighten.

9.0 TROUBLESHOOTING

Unit will not transmit:

1. Is the selected interrogate frequency correct for the unit?

2. Is the TR-7000 turned on?

3. Is the Enable Board timed out? Send an Enable Command, see Section 4.2.3.

4. Reposition the deck unit transducer and try again.

9.1 Detailed Electronic Troubleshooting

The following guide will enable an electronic technician with an oscilloscope to step through the basic operation of the TR-7000. If there is a problem, this procedure should help the technician find the particular circuit or component that is not operating properly.

a. Turn the TR-7000 OFF by taping the magnet over the Magnetic Switch.

b. Open the glass housing and expose the P.C. boards.

> **IMPORTANT: Be careful!** Potentially harmful voltages will be present in the vicinity of the transformer and inductor on the Driver/Preamp board.

c. If the problem appears to be premature battery drain, unplug the battery pack and attach a 13.5 volt DC power supply in its place. Negative supply (or ground) is the center pin and positive supply (13.5v) is either side pin. Turn the TR-7000 ON and check that the standby current drops to less than 4 ma after the capacitors charge. Peak charging current will be as high as 3 amps. Sleep current should be less than 1.4 ma.

d. The following is a list of important test points and a description of the signals that should be present. Most of the test points are on J2, the test connector on the synthesizer board. There are also TP_ test points on the CPU board and Driver/Preamp Board.. Refer to Figures 5-1 and 5-2 for the exact positions. Be careful not to short adjacent test points together. Turn the TR-7000 ON and proceed with tests (reference Figure 5-5, Circuit Flow Diagram.).

J2-1	DP	Goes low to initiate program load for the FPGA
J2-2	MOT_CTL	N/A
J2-3	Sina	Multiuse frequency. Usually at 8.75Khz when unit is awake. No signal when unit is asleep.
J2-4	Cosa	Quadrature version of Sina
J2-5	Sinb	Receive frequency from synthesizer
J2-6	Cosb	Quadrature version of Sina

J2-7	Phase	Gated output frequency from synthesizer to Driver
J2-8	+5V	Main logic supply, from switching regulator
J2-9	Phase/	Complement of Phase except for guard band
J2-10	Ampout	Preamp output, less last 20db stage on CPU board
J2-11	Battery	There is a 5A picofuse between this point and the battery
J2-12	AGND	AGND and GND are connected only on the Driver/Preamp board
J2-13	GND	
J2-14	+9.2V	
J2-15	TUNE_CTL	Used to reset Synthesizer prior to program reload
J2-16	MISO	SPI serial bus input (reserved)
J2-17	128Khz	Timing oscillator for synthesizer, noise, and Enable timer
J2-18	PHASEAEN	Enable for gated frequency
J2-19	PHASEBEN	Enable for gated frequency
J2-20	SAMPLE2	Enable for synthesizer B. If low, sampling reduced to 64Khz
J2-21	SAMPLE1	Enable for synthesizer A. If low, sampling stopped.
J2-22	EXT_CTL	reserved for specials
J2-23	OUT_EN/	Enable level shifter when low
J2-24	MOSI	SPI serial bus output
J2-26	SCK	SPI serial bus clock
J2-27	SYN1_EN	Enable setup word transfer for synthesizer A
J2-28	SYN2_EN	Enable setup word transfer for synthesizer B
J2-29	DIN	Data line for programming FPGA
J2-30	CCLK	Clock for loading FPGA program

Driver/Preamp test points:

TP1	Preamp after 15db gain.
TP2	Preamp after 35db gain

CPU test points:

TP1	Sync for self-test time-of-flight (neg)
TP2	Frame viewer for M-FSK detection (neg)
TP3	Detect envelope
TP4	Noise injection amplitude
TP5	Wakeup interrupt (neg)
TP6	preamp output after 62db gain and 16Khz noise injection

10.0 STORAGE

The TR-7000 uses an alkaline battery pack. Therefore, the longest shelf life may be obtained by storing the unit in its shipping container in a cool place (refrigerate if possible). De-rate all life specifications by 5% per year of storage at room temperature (+25° C).

TO AVOID OVERHEATING, DO NOT LEAVE THE UNIT UNPROTECTED FOR LONG PERIODS OF TIME IN DIRECT SUNLIGHT.

11.0 LIST OF DRAWINGS

Spare Parts Kit A-210-216 BOM

Re-arming Kit A-210-226 BOM

APPENDICES

Appendix A List of RS-232 Commands

Appendix B TR-6000 Transmit Beam Pattern

Appendix C Application Note #210-003, Alkaline Batteries

Appendix D Application Note #500-001, Minimum Detectable Signal of Underwater Transponders

Appendix E 6000 Series Acoustic Transponders Data Sheet

APPENDIX A

List of RS-232 Commands

Commands for the 7000 Series Transponders mimic the DS-7000 2 letter commands. They consist of two letters followed by either no data (echo current value) or data (change current value). Each of the commands will accept only the correct datatype (HEX, decimal, or ASCII) with a maximum correct number of digits or decimal places. Example, the RX command will accept up to 3 decimal places, thus 11.000, 11.00, 11.0, or 11 are all valid. 11.0000 would not be valid. Commands that are read only will ignore any data after the command. SAVE, DEF, and RESET are the only multiple letter commands.

The carriage return can be used at any time to repeat the previous command entered. On power-up, the repeat command option (carriage return only) will display the software version.

The command 'ZZ' can be used to enter and leave the Benthos Test Mode which includes commands only for test purposes. The prompt on the screen will change from the familiar '@' to '>' when in the Test Mode.

Spaces and '=' are ignored.

Invalid commands or data will result in 'ERR?'.

There are three types of commands, Read/Write, Read Only, and Execute.

Definition of Data Symbols

Decimal number
x ASCII HEX
a ASCII Character

System Status

SS	Read RX, TX, SX, SR, PL, ID, BA-BH, VO, and TT.

Read/Write Commands

RX ##.###	Write receive frequency as xx.xxx with quantizing to nearest possible frequency Illegal frequencies, 8.75, 12.5, 16.0, 18.0 Khz.
TX ##.###	Write transmit frequency as xx.xxx with quantizing to nearest possible frequency Illegal frequencies, 8.75, 12.5, 16.0, 18.0 Khz.
SR ##.###	Write Smart (substitute) receive frequency as xx.xxx with quantizing to nearest possible frequency Illegal frequencies, 8.75, 12.5, 16.0, 18.0 Khz.

SX ##.### Write Smart (substitute) transmit frequency as xx.xxx with quantizing to nearest possible frequency
Illegal frequencies, 8.75, 12.5, 16.0, 18.0 Khz.

BA a Write Benthos 'A' command assignment.
BB a Write Benthos 'B' command assignment.
BC a Write Benthos 'C' command assignment.
BD a Write Benthos 'D' command assignment.
BE a Write Benthos 'E' command assignment.
BF a Write Benthos 'F' command assignment.
BG a Write Benthos 'G' command assignment.
BH a Write Benthos 'H' command assignment.

where **a** can be

N	Null
S	Set Bit
C	Clear Bit
E	Enable
D	Disable
R	Release
M	Missed Ping
O	Demo an M-FSK command reply

ID ## Write ID in decimal, 0 to 63.

PL ##.## Write Ping Length in milliseconds quantized, 26.56 maximum

TA ##.## Write Turnaround time in milliseconds quantized, 53.12 maximum

MI ###Write Missing Int value in decimal, maximum of 255

PR ###.# Write Period in seconds, quantizing to nearest .5 sec, 127.5 maximum

IN ###.# Write Inhibit (Lockout) in seconds quantizing to nearest .5 sec, 127.5 maximum

CK a Write Enable Clock as 'D'ays, 'H'ours, or 'M'inutes

PE ### Write Ping Enable in decimal, maximum of 99

NS ## Write Noise byte in decimal, maximum of 99

OT ## Write Other Transponder's ID in decimal, 0 to 63

DA xxxx Write 2 Data bytes to memory in ASCII HEX

Read Only Commands

ST	Read status word in HEX, ST=xx
DP	Read doppler measurement in decimal, DP=###
SC	Read signal strength sine, cosine in decimal, SS=###,###
TI	Read Active Time in power of 2 exponential form, TI=###e### (### * $2^{###}$)
TT	Read Total Time since Reset in decimal, TT=##:##:##:##:## (MM:DD:HH:MM:SS)
VO	Read Battery Voltage in decimal volts, VO=##.#
NP	Read Number of Pings in power of 2 exponential form, NP=###e### (### * $2^{###}$)
VE	Read Version of Software, VE=##.##

Execute Commands

SAVE	Save information to non-volatile memory
RESET	Forced Reset of TR-7000
DEF	Restore default values.

Test Commands only accessible after sending 'ZZ' with prompt '>'

Send another 'ZZ' to toggle back to standard mode.

Configuration Command

LM a	Write Frequency Range as 'L'ow or 'M'edium RESET must be executed before LM takes affect.

Benthos Commands

XA	Send Benthos A command
XB	Send Benthos B command
XC	Send Benthos C command
XD	Send Benthos D command
XE	Send Benthos E command
XF	Send Benthos F command
XG	Send Benthos G command
XH	Send Benthos H command

NOTE: The eight Benthos Commands described above are not meant to be used by the customer if a standard transducer is attached. They could damage the unit or cause a fire due to their long duration!

TR Commands

TS	Go to sleep
TP	Ping once, Return Time-of-Flight in BCD
TM	Send MS byte
TL	Send LS byte
TQ	Request MS byte, LS byte, display in Hex if sent
TH	Change ID
TE	Enable TR#nn and self
TD	Disable TR#nn and self
TR	Release TR#nn
TY	Release self
TZ	Read Awake Time from TR#nn, display
TB	Change RX Freq of TR#nn
TC	Change TX Freq of TR#nn
TN	Set noise and enable for TR#nn
TG	Disable Noise for TR#nn
TF	Send Command previously stored to TR#nn

Appendix B

INSERT BEAM PATTERN

TR-6000 Transmit Beam Pattern