SonTek®

A YSI Environmental Company

SonTek/YSI ADP®
Acoustic Doppler Profiler
Technical Documentation

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SonTek ADP® Introductory Documentation
Software Versions 5.0 through 6.45
Firmware Versions 5.0 through 7.1

ADP (Acoustic Doppler Profiler) is a registered trademark of SonTek Inc.

Thank you for purchasing an ADP from SonTek/YSI. We are confident you will find it powerful, accurate, reliable and easy to use.

This document provides a "Quick Start" introduction to using the ADP and should contain enough information to get started and to collect some data.

To learn more about the ADP, we encourage you to read the ADP Principles of Operation. It covers the physical principles of ADP operation and provides some background for analyzing ADP data. We also suggest reading the ADP Operation and Software Manuals. These manuals cover a wide range of ADP applications, so not all of the information will pertain to your system. At the end of this document are lists of the important sections in the Operation and Software Manuals for some of the most common ADP applications and functions.

The following series of instructions should be enough to get started with the ADP and collect some sample data.

1) **Software Installation**
   Create a directory on your PC for the ADP software, and copy all files and directories from the enclosed disk to that directory. All software is written for DOS on PC-compatible computers. Several of the ADP software programs will not operate reliably from the "DOS Prompt" within Windows/Windows95; memory resident programs in Windows can interfere with serial port operation. Exit Windows and operate the computer in a dedicated DOS mode.

2) **Real-Time Data Acquisition Software**
   Plug the communication cable into the ADP, connect the power supply, and plug the serial connector into COM1 on your computer. From the ADP directory, type "ADPSA" at the DOS prompt. Follow the instructions on the screen (using the arrow keys) to change parameters in the setup menu. Use a short averaging interval (15 seconds) for initial testing and select a data file to record some test data.. Press "Start Data Acquisition". Allow the ADP to collect a few minutes worth of data before stopping data collection by pressing Alt+F10; exit the program and return to DOS.

3) Data Conversion

Use the "GADP___" programs to convert the binary data file created above to ASCII format. For information on using any of these programs, type the program name at the DOS prompt. Look at the ASCII output files using a text editor or data processing software of your preference. See the ADP Software Manual for details.

4) Direct Command Interface

From the DOS prompt type "SONTERM". Select a log file by pressing Alt+F. Press ALT+B to wake the instrument up. Type "Help <CR>" to get started. Type "Show <CR>" to display system configuration. Select some reasonable operating parameters (set "OutFormat ASCII" and use an averaging interval of about 15 seconds). For ADPs without the internal recorder, begin data collection with "Start"; with the internal recorder, specify a deployment name (using the command "Deployment <name>") and begin data collection with "Deploy".

5) Recorder Data Extraction

From the DOS prompt type "SONREC 1". Mark a file on the recorder (using the SPACE key) and retrieve the file to the computer hard disk (press F3). Extract data from the binary file using the GADP___ programs.

6) Compass Calibration

From the DOS prompt type "COMPCAL 1". Move the ADP to see the response of heading, pitch and roll. If performing a calibration, be sure to complete the entire procedure; partial calibration can have adverse effects on heading data.

The ADP has been designed to be reasonably robust, so don't be afraid to try different things. If you have any questions, comments or suggestions, please give us a call, send a fax, or write an email.

Important Manual Sections for Common ADP Applications

Basic Operation

    ADP Operation Manual
        Section 1.1 – ADP Components
        Section 1.2 – Definitions and Terminology
        Section 2.1 – Real Time Data Collection with SonTek Software
        Section 5.2 – ADP Internal Electronics and Wiring Overview
        Section 5.4 – Cables and Connectors
        Section 6.3 – ADP Coordinate System
    ADP Software Manual
        Section 1 – Software Summary
        Section 2 – Real Time Data Collection (ADPSA)
        Section 3 – Data Conversion (GADP___)

Direct Communication with the ADP
   ADP Operation Manual
      Section 2.2   – Real Time Data Collection Using Serial Output Data
      Section 3.1   – Modes of Operation
      Section 3.4   – Direct Command Summary
      Section 3.15 – Output Data Format
   ADP Software Manual
      Section 5 – Terminal Emulator (SONTERM)

Autonomous Deployment: Internal Recording and Battery Power
   ADP Operation Manual
      Section 1.3 – ADP Sampling Strategies
      Section 2.3 – Autonomous Deployment
      Section 3   – Direct Command Interface (primarily used as a reference)
      Section 7   – Autonomous Deployment (perhaps the best source of information)
   ADP Software Manual
      Section 5 – Terminal Emulator (SONTERM)
      Section 6 – Recorder Data Extraction (SONREC)

Compass/Tilt Sensor
   ADP Operation Manual
      Section 4.1 – Testing Compass Operation
      Section 4.2 – Compass Installation and ADP Orientation
      Section 4.4 – Compass Calibration
   ADP Software Manual
      Section 4 – Compass Calibration (COMPCAL)

Temperature and Pressure Sensor
   ADP Operation Manual
      Section 6.5 – Temperature and Pressure Sensors

Maintenance and Trouble Shooting
   ADP Operation Manual
      Section 6.7 – Routine Maintenance
      Section 6.8 – Trouble Shooting

Moving Vessel Applications with GPS Positioning
   ADP Software Manual
      Section 2.5 – Integrated GPS Position Data
      Section 3.4 – GPS Data Conversion

Considerations for Specialized ADP Systems
   ADP Operation Manual
      Appendix B – PC-ADP Settings and Operational Considerations
      Appendix C – L-ADP Settings and Operational Considerations

Special Notice when Turning Computers On or Off

When many computers and data loggers are turned on or off, they send a signal out the serial port that can interpreted as a BREAK. If the ADP is connected to the serial port, this can interrupt data collection or bring the ADP out of sleep mode. This may cause the loss of data or the draining of batteries. Always disconnect the ADP from the computer or data logger prior to turning it on or off.

We wish you the best of success with the ADP and we look forward to hearing about your experiences. If you have any questions, comments, or need any additional assistance, please don't hesitate to contact us.

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A YSI Environmental Company

ADP® (Acoustic Doppler Profiler) Operation Manual Firmware Version 7.1

ADP (Acoustic Doppler Profiler) is a registered trademark of SonTek/YSI, Inc.

WARRANTY, TERMS AND CONDITIONS

Thank you for purchasing a SonTek Acoustic Doppler Velocity sensor. The instrument was thoroughly tested at the factory and found to be in excellent working condition. If the shipping crate appears damaged or if the system is not operating properly, please contact SonTek immediately.

The System you have purchased is covered under a one year limited warranty that extends to all parts and labor for any malfunction due to workmanship or errors in the manufacturing process. The warranty does not cover shortcomings that are due to the design, nor does it cover any form of incidental damage as a result of errors in the measurements.

In case your System is not functioning properly, first try to identify the source of the problem (refer to the appropriate section of the manual for a trouble shooting advice). If additional support is required, we encourage you to contact us immediately if a problem is detected and we will work to resolve the problem as quickly as possible. Most problems can be resolved without a system being returned to us.

In case the system needs to be shipped back to the factory please contact SonTek to obtain a Return Merchandise Authorization (RMA) number. We reserve the right to refuse receipt of shipments without RMAs. We require the system to be shipped back in original shipping container using original packing material and all delivery cost to SonTek covered by the customer (including all taxes and duties). If the system is returned without appropriate packing the customer will be required to cover the cost of new packaging crate and material.

INTRODUCTION

This manual is organized into the following sections:

- **Section 1. ADP Components, Terminology, and Sampling** - naming conventions and terms used in this manual, and a general description of ADP sampling strategies.

- **Section 2. Getting Started** – general instructions for collecting data with the ADP in the most common configurations.

- **Section 3. Direct Command Interface for the ADP** - direct communication with the ADP, including command format, options and output data format.

- **Section 4. Compass/Tilt Sensor Operation** - concerns and procedures relating to the internal compass and tilt sensor.

- **Section 5. ADP Hardware`** – description of the ADP electronics, cables, connectors, internal jumpers/switches, and instructions for accessing system components.

- **Section 6. Operational Considerations** - concerns and procedures relating to power supply, instrument mounting, coordinate systems, external sensors, maintenance and troubleshooting.

- **Section 7. Autonomous Deployment** – instructions for initiating an autonomous deployment.

- **Section 8. ADP Optional Features**– describes ADP optional wave package SONWAVE, bottom track and external sensors.

- **Section 9. Additional Support** – contact information for additional customer support.

- **Appendix A ADP Binary Data File Format** – a detailed description of the ADP binary data file format.

- **Appendix B PC-ADP Settings and Operational Considerations** – a description of operational differences between the standard ADP and a pulse-coherent ADP.

- **Appendix C L-ADP Settings and Operational Considerations** – a description of operational differences between the standard ADP and a Lowered-ADP system.

TABLE OF CONTENTS

SECTION 1.   ADP Components, Terminology and Sampling

1.1.   ADP Components

The ADP includes a number of different components, the exact nature of which vary with instrument configuration. The list below gives a brief description of all major system components and their function.

- ADP sensor - The sensor consists of two or three acoustic transducers (for 2D or 3D profiling) and receiver electronics. The transducers are mounted in an aluminum head that is anodized and polyester powder coated. The head is mounted to the ADP housing the size of which varies with system configuration; the housing is anodized, polyester power coated, and includes zinc anodes for corrosion protection. The compass/tilt sensor is mounted inside the sensor housing.
- ADP processor - The ADP processor can be packaged two ways: in a splash-proof (non-submersible) housing ("Low Profile ADP") or in the same underwater housing as the ADP sensor ("Stand-alone ADP"). The electronics consist of three printed circuit (PC) boards with an optional fourth board for internal recording. The processor sends and receives signals from the ADP sensor, performs Doppler calculations to compute the velocity profile, controls the operation of all other sensors, and outputs the data over the serial port and to the internal recorder.
- High-frequency cable - This cable, used with the Low Profile ADP only, carries analog signals between the ADP sensor and processor. Because of the nature of the analog signals, the cable has a maximum length of 60 m. This is a custom shielded cable designed specifically for this application and should not be modified by the user.
- Power and communication cable - This cable carries DC input power (12-24 V) and 2-way serial communication between the ADP processor and the controlling computer. The ADP supports RS232 serial communication for cable lengths to 100 m (300 ft) and RS422 for cable lengths 1500 m (4500 ft).
- Splitter cable - This cable connects the Stand-alone ADP to an external battery back for autonomous operation. The cable has one connector to the ADP, one to the battery pack, and a third to the power and communication cable (sealed with a dummy plug during deployment).
- Temperature sensor - The temperature sensor, standard on all ADPs, is mounted internally in the ADP sensor housing. Temperature data automatically compensate for changes in sound speed; sound speed converts Doppler shift to water velocity. See section 6.5 for more details on the temperature sensor.
- Compass/tilt sensor - This optional sensor measures magnetic heading and 2-axis tilt (maximum tilt ±50°); it is mounted in the same underwater housing as the ADP sensor. This allows the ADP to report velocity measurements in Earth (East - North - Up) coordinates. The compass includes a built-in calibration feature to compensate for ambient magnetic fields (see section 4.4). See SECTION 4 for more details on the compass/tilt sensor.
- Pressure sensor - The optional pressure sensor is mounted in the ADP sensor head between the acoustic transducers. A small signal processing board for the pressure sensor is installed near the receiver board. See section 6.5 for more details on the pressure sensor.

- <u>Battery power</u> - The ADP can include battery power for autonomous deployment or to act as a backup in the event of shore power failure. The batteries can be housed in an external canister connected by a splitter cable, or in the same extended underwater housing as the ADP processor. See section 7.2 for details on autonomous operation from battery power. See Appendix 2 for details on battery pack construction. See section 5.9 for details on accessing the batteries.

1.2.   Definitions and Terminology

This section defines terms commonly used when working with the ADP.

- <u>Direct command interface</u> - direct serial communication with the ADP processor.
- <u>BREAK</u> - a serial communication signal that causes a hardware reset in the ADP electronics and returns the system to command mode. A BREAK consists of holding the ADP input serial communication line high for a period of at least 300 milliseconds.
- <u>Ping</u> - a single estimate of the water velocity profile. A ping consists of each transducer sending a short acoustic pulse, calculating the along-beam velocity profiles, and combining data from all beams (and the internal compass/tilt sensor if enabled) to compute the velocity profile.
- <u>Profile</u> - in addition to its more general use, profile refers to the collection of a number of pings to produce a mean estimate of the water velocity at each depth cell. A profile includes velocity, standard deviation, and signal strength data.
- <u>Temperature</u> - water temperature, in °C. Either default temperature inputted by the user, or measured using an internal sensor. Mean and standard deviation of measured temperature are recorded with each profile. Temperature is used for sound speed calculations.
- <u>Salinity</u> - water salinity, in ppt. The value input by the user is for sound speed calculations.
- <u>Sound speed</u> - speed of sound, at the transducer face, in m/s. This converts Doppler shift to water velocity. Sound speed is either calculated from user-specified temperature and salinity, or from measured temperature and user-input salinity (see the command "TempMode" in section 3.7). See the ADP Principles of Operation for details on the effects of sound speed.
- <u>Blanking distance</u> - the region in front of the transducers where no measurements can be made, in meters (m). This is measured as the vertical distance from the ADP transducers to the start of the first depth cell. The blanking region is required for the transducers and electronics to recover from the transmit pulse.
- <u>Depth cell size</u> - this defines the resolution of the velocity profile, in m. This is specified as the vertical distance from the ADP, and not the range along the path of the acoustic beams. See ADP Principles of Operation for details on the exact definition of ADP depth cells.
- <u>Number of cells</u> - the number of cells collected in each profile.
- <u>Depth cell location</u> - to calculate the location of the center of each depth cell, multiply the depth cell number (starting with 1 closest to the ADP) by the depth cell size and add the blanking distance. See "ADP Principles of Operation" for details regarding depth cell size and location.
- <u>Pinging rate</u> - the number of pings per second, in Hz. This is normally determined by the propagation speed of sound, although the variable "Ping Interval" can be selected to achieve a slower pinging rate for certain applications (see sections 3.7, 7.1 and 7.2).

- Profile time - the ADP records date and time from its internal clock with each profile. The recorded time represents the start of the averaging interval.
- Averaging interval - the period of time, in seconds, over which the ADP averages data to compute a mean velocity profile.
- Profile interval - the time between sequential profiles, in seconds. This is given as the time from the start of one profile to the start of the next profile, and must be greater than or equal to the averaging interval (or averaging interval will take precedence).
- Ping interval - the minimum time between sequential pings, in seconds. The default setting of 0.0 seconds causes the ADP to ping as rapidly as possible. Although not common, this can save power in applications where long averaging intervals are required to remove real variations in water velocity (see sections 3.7, 7.1, and 7.2).
- Burst sampling - this sampling method allows the user to record a number of profiles in rapid succession, and then put the ADP in sleep mode for an extended period of time. This is to record data on the short-term and long-term variation of water velocity, while maintaining a reduced duty cycle to conserve battery power and limit data storage requirements.
- Burst interval - the period of time, in seconds, between each sampling burst (when burst sampling is enabled). This is measured from the start of one burst to the start of the next burst, and must be greater than the time required for each burst.
- Profiles per burst - the number of profiles recorded during each burst, used only when burst sampling is enabled.

1.3. ADP Sampling Strategies

A number of the terms defined in section 1.2 determine the exact sampling strategy used by the ADP. These include ping, ping interval, averaging interval, profile interval, burst interval, and profiles per burst. These terms, and the different sampling strategies used by the ADP, are illustrated in Figure 1.

The ADP supports three basic sampling strategies. Continuous sampling is used for real-time data collection when connected to shore power or for autonomous deployments without power or data limitations. For continuous operation, the ADP profile interval is set to the same value as the averaging interval, and the ADP is actively collecting data at all times (except for the ~1 sec overhead time required for each profile).

For typical autonomous deployments, the ADP operates using a reduced duty cycle where the profile interval is greater than the averaging interval. When the ADP is not collecting data, it enters a sleep mode where power consumption is less than 1 mW. Duty cycle is calculated as the ratio of the averaging interval to the profile interval. Battery life is extended by the inverse of the duty cycle. For example, an averaging interval of 5 minutes with a profile interval of 15 minutes gives a 33% duty cycle and extends battery life by a factor of 3.

The final sampling strategy, burst sampling, enables the user to obtain information about short-term flow variation without requiring continuous operation. In this mode, the ADP collects a number of profiles in rapid succession and then enters a sleep mode to conserve power. Duty cycle is calculated by the following formula.

```
Duty cycle = (Profiles_per_burst * Averaging_interval) / Burst_interval
```

ADP Profile

Ping

Ping

Averaging

Time

Continuous

Averaging Interval = Profile

Time

Autonomous Sampling - Reduced Duty

Profile

Averaging

Time

Burst

Averaging

Burst

Profiles per

Profile

Time
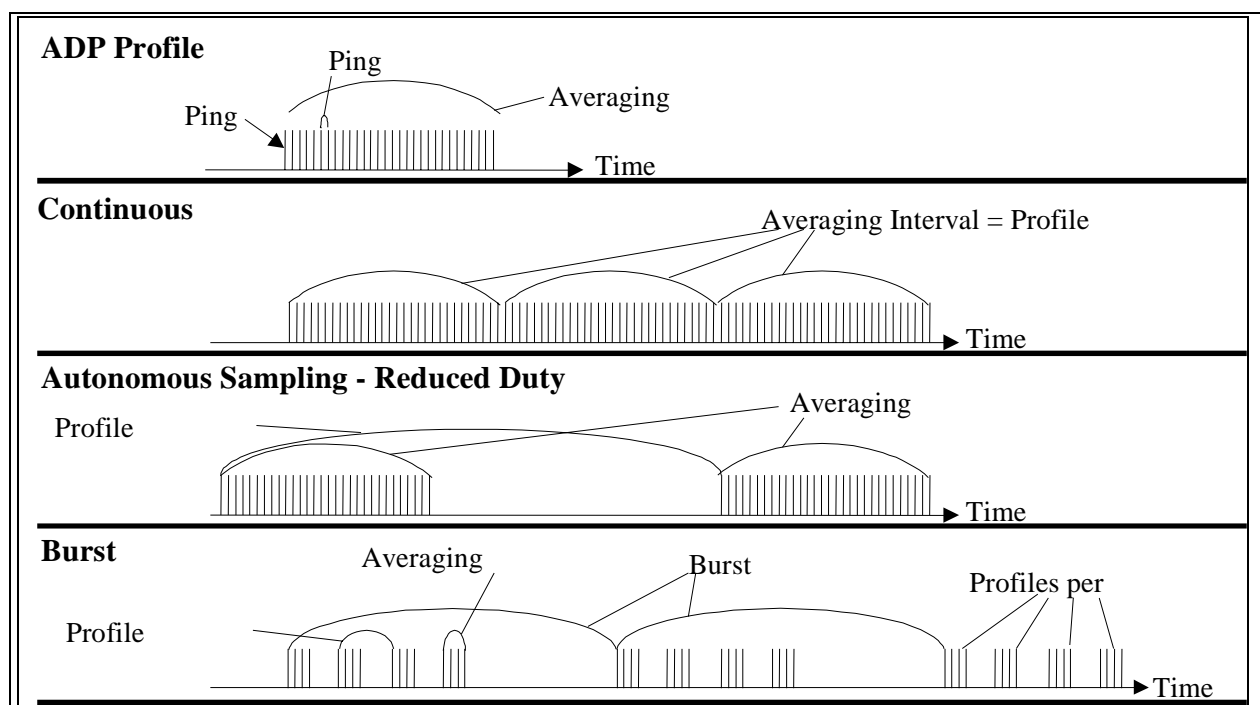
Figure 1 - ADP Sampling Strategies

SECTION 2.   Getting Started

This section contains basic instructions for collecting data with the ADP in three of the most common configurations. These instructions are not intended to be comprehensive, but should be sufficient to get started and collect data for preliminary analysis.

Note that the testing described here can be done with the system in air without any damage to the ADP, although the velocity data from the instrument will be meaningless. When becoming familiar with ADP operation, we suggest that you begin with some basic testing with the system in the air and then move to preliminary field tests (from a dock or small boat) to gain experience.

2.1.   Real-Time Data Collection with SonTek Software

The easiest way to collect ADP data is with the real-time data collection software, ADPSA.EXE. This software is described in detail in the ADP Software Manual. Basic instructions for collecting data using ADPSA are given below.

1. Copy all files from the ADP software diskette to a directory on the controlling computer. Place the computer in a dedicated DOS mode (not a DOS prompt within Windows).
2. Connect the ADP power and communication cable from the instrument to COM1 of the controlling computer and to the external power supply included with the system.
3. Type "ADPSA" at the DOS prompt. The software will establish communication with the ADP and download the current system configuration.
4. Select the desired operating parameters from the setup menu. For initial testing, we recommend using a relatively short averaging interval (perhaps 10-15 seconds) to speed up the data collection process. Specify a recording file to capture data to the computer hard disk.
5. Select "Start Data Acquisition" from the setup menu. The software will configure the ADP and begin data collection. Allow the ADP to collect several minutes of data.
6. Stop data collection by pressing Alt+F10. After confirmation, the program will return to the setup menu. Select "Exit Data Acquisition" to return to the DOS prompt.
7. Use the GADP___.EXE programs to extract different portions of the binary data file to ASCII format. See the ADP Software Manual for details on program operation, and the ADP Principles of Operation for details on interpreting the different types of ADP data.

2.2.   Real-Time Data Collection using Serial Output Data

For real-time data collection, the ADP is often integrated with a variety of data collection systems using the direct command interface and serial output data. For this type of integration, it may be helpful to gain experience with the system using the terminal emulator SONTERM included with the ADP software. Basic instructions for getting started are given below. For more information on the direct command interface and output data format, see SECTION 3.

1. Copy all files from the ADP software diskette to a directory on the controlling computer. Place the computer in a dedicated DOS mode (not a DOS prompt within Windows).
2. Connect the ADP power and communication cable from the instrument to COM1 of the controlling computer and to the external power supply included with the system.
3. Type "SONTERM" at the DOS prompt.

4. Capture all communication with the ADP to a file for future reference using the Alt+F option in SONTERM.
5. Press Alt+B to send a BREAK to the ADP and bring the system into command mode (the ADP command prompt is ">").
6. Begin using the direct command interface by typing "Help" at the command prompt. This will lead you into a number of menus displaying available commands.
7. Use the four "Show" commands ("Show Conf", "Show System", "Show Setup", and "Show Deploy") to display all ADP hardware and operating parameter settings.
8. Type "Compass CONT" to display data from the internal compass/tilt sensor. Rotate and tilt the ADP to verify compass operation (see section 4.1). Press any key to stop data output.
9. Type "Sensor CONT" to display data from the temperature, pressure, and battery voltage sensors (see sections 3.10 and 6.5). Press any key to stop data output.
10. Type "Dir" to view the contents of the internal recorder, if installed.
11. Select reasonable operating parameters for trial data collection. Use relatively small values for averaging interval and profile interval (10-15 seconds), and collect a relatively small number of cells (~10). Select the output format as ASCII.
12. Begin data collection immediately with the "Start" command.
13. Allow the ADP to output a number of profiles, then exit SONTERM (Alt+X) and take a closer look at the output data in the file specified earlier.

2.3.   Autonomous Deployment

Autonomous deployments use the optional ADP internal recorder and battery power. SECTION 7 contains detailed instructions for initiating autonomous deployments. This section provides a brief overview of the steps used to collect a sample deployment from external power. It assumes the user has already followed the steps in Section 2.2 and has a basic familiarity with the direct command interface.

1. Copy all files from the ADP software diskette to a directory on the controlling computer. Place the computer in a dedicated DOS mode (not a DOS prompt within Windows or Windows95).
2. Connect the ADP power and communication cable from the instrument to COM1 of the controlling computer and to the external power supply included with the system.
3. Type "SONTERM" at the DOS prompt.
4. Capture all communication with the ADP to a file for future reference using the Alt+F option in SONTERM.
5. Press Alt+B to send a BREAK to the ADP and bring the system into command mode (the ADP command prompt is ">").
6. Use the four "Show" commands ("Show Conf", "Show System", "Show Setup", and "Show Deploy") to display all ADP hardware and operating parameter settings.
7. Set reasonable values for cell size and the number of cells. Select relatively short values for averaging interval and profile interval (10-15 seconds) and disable burst sampling. Make sure the deployment start-date and time are before the current date and time shown on the ADP internal clock. Specify a deployment name for the recorded data.
8. Begin autonomous data collection with the "Deploy" command.
9. Allow the ADP to output a number of profiles, then exit SONTERM (Alt+X).

10. Type "SONREC 1" at the DOS prompt to start the recorder data retrieval software. When the directory is displayed, mark the file you have just generated using the SPACE key and download by pressing the F3 key. See the ADP Software Manual for more details. When the data file has been downloaded, exit SONREC by pressing the ESC key.

11. Use the GADP___.EXE programs to extract different portions of the binary data file to ASCII format. See the ADP Software Manual for details on program operation, and the ADP Principles of Operation for details on interpreting the different types of ADP data.

SECTION 3.   Direct Command Interface

The ADP communicates with external devices using RS232 or RS422 serial communication protocol. The choice of protocol is set using jumpers in the ADP electronics (see section 5.7). The baud rate is set using a rotary switch in the ADP electronics (see section 5.6); the default setting is 9600. The fixed communication parameters are: 8 data bits, no parity, 2 stop bits.

Prior to data collection, the user must set a number of operational parameters. This can be done using direct commands or using the software provided with the ADP. This section describes the direct command interface using a terminal or terminal emulator (such as SONTERM supplied with the ADP software).

Section 3.1 gives an overview of the operational modes of the ADP. Section 3.2 gives an important notice about the behavior of the ADP when the power is source is changed. Section 3.3 presents the syntax rules for the command interface. Section 3.4 gives a summary of all available commands. The remaining parts of this section (3.5 through 3.14) describe each command in detail and give a detailed description of the output data format.

3.1.   Modes of Operation

The ADP has four operational modes:

- Command Mode
- Data Acquisition Mode
- Deployment Mode
- Sleep Mode

Each is described below. See section 3.3 for details regarding command syntax and the definition of a BREAK.

Command mode
In command mode the ADP can send and receive commands related to all aspects of instrument operation. The user can enter the command mode from any other mode by sending a BREAK. The user can put the ADP into any of the other modes only from the command mode. The user can enter the command mode from the data acquisition mode or the deployment mode by sending a BREAK or the run time command "+++".

To enter the data acquisition mode from the command mode, use the command "Start". To enter the deployment mode from the command mode, use the command "Deploy". To enter the sleep mode from the command mode, use the command "PowerOff". If the ADP is left idle in the command mode for more than 5 minutes, it will automatically enter the sleep mode to conserve power.

Data acquisition mode
Data acquisition mode is for real-time data collection. Data acquisition mode is entered from command mode with the command "Start". After receiving the "Start" command, the ADP takes a few seconds to initialize and then begins data collection. In data acquisition mode, the ADP ignores the deployment parameters "StartDate" and "StartTime". If the internal recorder is installed and has been enabled ("Recorder ON"), profile data are output both over the serial port and to the internal recorder. If the recorder is not installed or has been disabled ("Recorder

OFF"), data are sent only to the serial port. The user can exit the data acquisition mode and return to the command mode by sending a BREAK or by using the run time command "+++".

While in data acquisition mode, the ADP can enter a power saving state if there is sufficient time between profiles. This power saving state is similar to, although not the same as, the sleep mode. The ADP will enter the power saving state if there is more than 10 seconds between profiles and the system command "AutoSleep" is set to ON (the default setting).

While collecting data, several run-time commands are available to simplify ADP integration with external data acquisition systems. These commands are accessed by sending one or more characters to the ADP over the serial communication line; see section 3.13 for details. Run-time commands cannot be accessed if the ADP is in the power saving state.

Deployment mode
Deployment mode is for autonomous data collection. Deployment mode is entered from command mode using the command "Deploy". In deployment mode, the instrument will begin collection with the most recently entered setup parameters at the date and time specified by "StartDate" and "StartTime". If the current date and time are after the specified start date and time, the system will begin data collection immediately. Deployment mode can only be used when the ADP includes the internal recorder. In deployment mode, data are always stored to the internal recorder regardless of the setting of the "Recorder ON/OFF" parameter.

In deployment mode, the ADP will enter a power saving state whenever there is more than 10 seconds between profiles (regardless of the setting of the "AutoSleep" parameter). The same run time commands are available in deployment mode as in data acquisition mode. The user can exit the deployment mode and enter command mode by sending a BREAK or by using the run time command "+++". Run-time commands cannot be accessed if the ADP is in the power saving state between profiles.

Sleep mode
Sleep mode is to conserve power when the ADP is not in use. The sleep mode is entered from the command mode using the command "PowerOff". In the sleep mode, the ADP consumes less than 1 mW of power. The user can exit the sleep mode and enter command mode by sending a BREAK. When in sleep mode, the ADP will not respond to any external commands except a BREAK. The only exception to this is if the primary system power is switched off and on (see Section 3.2). If the ADP is left idle in command mode for more than 5 minutes, it will automatically enter the sleep mode to conserve power.

3.2.   Special Notice When Changing Power Sources

When the main power to the ADP is turned off and on (i.e. when changing batteries or switching power supplies), the ADP will enter the mode it was in before power was lost. If previously in command mode or sleep mode, it will re-enter command mode. If previously in data acquisition mode, it will enter data acquisition mode and immediately start real-time data collection. If previously in deployment mode, it will start a new deployment using the stored operating parameters with the exception of "StartDate" and "StartTime". These parameters are ignored and the new deployment will begin immediately. This is a safety feature to avoid data loss in the event of clock reset caused by a problem with the real-time clock backup battery.

The ADP real-time data collection software leaves the instrument in data acquisition mode upon exiting. Thus, if power is cycled after running the data acquisition software, the ADP will immediately start real-time data collection. In some applications, particularly when interfacing the ADP with a data logger, the start and stop of data collection may be controlled by cycling the system power. For these applications, be sure that the ADP is in data acquisition mode prior to turning power off to ensure that data collection will begin immediately when power is applied.

When changing batteries, always establish communication and place the ADP in sleep mode after the change to prevent draining the batteries.

IMPORTANT: When many computers and data loggers are turned on or off, they send a signal out the serial port that can interpreted as a BREAK. If the ADP is connected to the serial port, this can interrupt data collection or bring the ADP out of sleep mode. This may cause the loss of data or the draining of batteries. Always disconnect the ADP from the computer or data logger prior to turning it on or off.

3.3. Command Syntax

These are the basic rules for communication between the ADP an external terminal, terminal emulator, or interface program.

Throughout this manual, we refer to a BREAK when discussing direct communications with the ADP. The BREAK is a serial communication signal that causes a reset in the ADP processor and places the instrument in command mode. A BREAK consists of holding the data input line high for a period of at least 300 milliseconds. Most terminal emulator programs have a key combination that sends a BREAK; the program SONTERM (supplied with the ADP software) uses Alt+B.

1. The ADP can be brought into the command mode from any other mode by sending a BREAK.
2. All commands consist of a single keyword that may be followed by one or more ASCII parameters. The commands and parameters are not case sensitive.
3. When the ADP has completed a command and is ready to accept another command, it will send the prompt character ">".
4. Parameters may be numeric (either integer or floating point), alphanumeric, or a combination (for example, a date or time string).
5. Commands must be terminated by a <CR>.
6. The ADP echoes every character as it is received (except for run-time commands received during data collection – see section 3.13).
7. After receiving the <CR> that signals the end of the command string, the ADP echoes an additional <LF>.
8. If the ADP recognizes a command as valid it will transmit: <LF>OK<CR><LF>.
9. If a command is not recognized, the parameters are out of range, or if the command cannot be executed in the present state, the ADP returns an error-message followed by <CR><LF>.

IMPORTANT: When many computers and data loggers are turned on or off, they send a signal out the serial port that can interpreted as a BREAK. If the ADP is connected to the serial port, this can interrupt data collection or bring the ADP out of sleep mode. This may cause the loss of data or the draining of batteries. Always disconnect the ADP from the computer or data logger prior to turning it on or off.

3.4.   Direct Command Summary

The tables below summarize all direct commands that can be used with the ADP, including any abbreviations (shorter versions of the same command). These commands are split into different sections, and different tables, based upon their function. Further details on individual commands are provided in the sections that follow.

The following abbreviations are input parameters to the ADP.

- d   Integer input (i.e. 30)
- d.d   Decimal real number input (i.e. 0.33, 1.5)
- yy/mm/dd   Date as year, month, and day (i.e. 1996/05/20 or 96/05/20)
- hh:mm:ss   24-hour clock with hour, minute, and second (i.e. 18:15:00)

Help Commands (Section 3.5)

Command	Short	Function
Help	H or ?	Available help categories
Help System	H/? System	General system commands
Help Setup	H/? Setup	Real-time data collection commands
Help Deploy	H/? Deploy	Autonomous deployment commands
Help Recorder	H/? Recorder	Data recorder commands
Help Sensor	H/? Sensor	Peripheral sensor commands
Help Compass	H/? Compass	Compass/tilt sensor commands
Help Show	H/? Show	Commands to display system configuration

System Commands (Section 3.6)

Command	Short	Function	Parameters
Start	(none)	Starts real-time data collection (enters data acquisition mode)	
Deploy	(none)	Starts autonomous deployment (enters deployment mode)	
Test	(none)	Perform built-in system test	
SaveSetup	(none)	Save current parameters to EEPROM	
Defaults	DEF	Sets all parameters to factory defaults	
Ver	(none)	Shows CPU firmware version	
DSPVer	(none)	Shows DSP firmware version	
BoardRev	(none)	Shows electronics board revision number	
SerNum	(none)	Returns ADP sensor serial number	
Date <date>	(none)	Sets system clock date	yy/mm/dd
Time <time>	(none)	Sets system clock time	hh:mm:ss
PowerOff	(none)	Puts ADP in sleep mode	
AutoSleep <mode>	AS	If ON, ADP enters reduced power state during gaps in data collection	ON or OFF
OutFormat <format>	OF	Specifies output data format	ASCII or BINARY
OutMode <mode>	OM	Selects data output mode	AUTO or

System Commands (Section 3.6)

Command	Short	Function	Parameters
			POLLED
Recorder <status>	(none)	Turns internal recording on or off	ON or OFF
RecMode <mode>	(none)	Sets recording mode	NORMAL or BUFFER

Setup Commands (Section 3.7)

Command	Short	Function	Parameters
Temp <temperature>	(none)	Sets default water temperature (°C)	d.d
Sal <salinity>	(none)	Sets default water salinity (ppt)	d.d
Ncells <number>	NC	Number of depth cells to record	d
CellSize <size>	CS	Vertical size of depth cells (m)	d.d
BlankDistance <distance>	BD	Distance to start of first cell (m)	d.d
AvgInterval <seconds>	AI	Profile averaging interval (s)	d
ProfileInterval <seconds>	PRI	Time between profiles (s)	d
PingInterval <seconds>	PGI	Time between pings (s)	d.d
CoordSystem <system>	CY	Coordinate system for velocities	BEAM, XYZ or ENU
TempMode <mode>	TM	Temperature for computing sound speed	USER or MEASURED

Deployment Commands (Section 3.8)

Command	Short	Function	Parameters
Deployment <name>	(none)	Set deployment name for internal recorder	ASCII text
Comments	(none)	Enter deployment comments	ASCII text
StartDate <date>	SD	Date when data collection begins	yy/mm/dd
StartTime <time>	ST	Time when data collection begins	hh:mm:ss
AvgInterval <seconds>	AI	Profile averaging interval (s)	d
ProfileInterval <seconds>	PRI	Time between profiles (s)	d
PingInterval <seconds>	PGI	Time between pings (s)	d.d
BurstMode <mode>	BM	Enables or disables burst sampling	YES or NO
BurstInterval <seconds>	BI	Time between sampling bursts (s)	d
ProfilesPerBurst <number>	PPB	Number of profiles per burst	d

Recorder Commands (Section 3.9)

Command	Short	Function	Parameters
Dir	(none)	List deployments currently on recorder	
LD	(none)	List deployments currently on recorder	
Format	(none)	Erase all data from recorder, re-format PCMCIA card for new data	
RecStatus	(none)	Show recorder size and free space left	
Recorder <status>	(none)	Turns internal recording on or off	ON or OFF
RecMode <mode>	(none)	Sets recording mode	NORMAL or BUFFER
OD <name>	(none)	Open deployment to access data	< deployment name>
CD	(none)	Return name of current open deployment	
RC	(none)	Retrieve configuration and setup information from currently open file	
RPA [N]	(none)	Retrieve next N profiles from file, ASCII format	<number of profiles>
RPB [N]	(none)	Retrieve next N profiles from file, binary format	<number of profiles>
FP	(none)	Go to first profile in deployment	
LP	(none)	Go to last profile in deployment	
GP <profile number>	(none)	Go to <profile number> in deployment	
CP	(none)	Return current profile number	
NP	(none)	Return number of profiles in deployment	

Sensor Commands (Section 3.10)

Command	Short	Function	Parameters
Sensor	(none)	Display most recent temperature, pressure. and battery voltage data	
Sensor CONT	(none)	Display continuous temperature, pressure. and battery voltage data	
PressOffset	(none)	Display pressure sensor calibration offset	
PressScale	(none)	Display pressure sensor calibration 1st order coefficient	
PressScale_2	(none)	Display pressure sensor calibration 2nd order coefficient	

Compass Commands (Section 3.11)

Command	Short	Function	
Compass	(none)	Display most recent heading, pitch, and roll data	
Compass CONT	(none)	Display continuous heading, pitch, and roll data	
Compass CAL	(none)	Perform a compass calibration	

Show Commands (Section 3.12)

Command	Short	Function
Show Conf	S Conf	Display hardware configuration parameters
Show System	S System	Display general system parameters
Show Setup	S Setup	Display real-time data collection parameters
Show Deploy	S Deploy	Display autonomous deployment parameters

Run Time Commands (Section 3.13)

Command *	Short	Function
+++	(none)	Return the ADP to command mode (stop data collection)
O	(none)	Transmit last profile
T	(none)	Transmit ADP date and time
C+	(none)	Adjust real-time clock +1 second
C-	(none)	Adjust real-time clock -1 second
N	(none)	Transmit profile number of last averaged profile
A	(none)	Transmit time left in current averaging interval (seconds)

* These commands available only in data acquisition and deployment modes

3.5. Help Commands

The ADP direct command interface contains a number of on-line help commands. These are designed such that, by starting with "Help" at the direct command interface, the user will be led through a series of menus that show all ADP commands. There are a total of 9 help commands that display all commands the user would normally use for any aspect of ADP operation.

- "Help"   Listing of help menus available
- "Help System"   General system commands
- "Help Setup"   Real-time data collection commands
- "Help Deploy"Autonomous deployment commands
- "Help Recorder"   Data recorder commands
- "Help Sensor"   Peripheral sensor commands
- "Help Compass"   Compass/tilt sensor commands
- "Help CTD"   External CTD sensor commands
- "Help Wave"   SonWave commands
- "Help Show"   Commands to display system configuration

The output of these commands is self-explanatory. For more details on individual commands, see the remaining portions of SECTION 3.

3.6.   System Commands

System commands relate to general operational concerns of the ADP. These functions include setting the clock, displaying the serial number, data output, recorder settings, and starting data collection. In this section, each command is shown (with any command line options) in *Italics*. Short versions of these commands, if they exist, are shown in parenthesis on the same line.

Start
This command starts real-time data collection, putting the ADP into data acquisition mode (see section 3.1). The ADP first saves all recently entered commands (commands will not be lost if a "SaveSetup" is not done prior to starting data collection). When using the start command, data collection begins immediately (Start Date and Time are ignored), and burst sampling cannot be used. Data will be stored to the recorder if it has been enabled ("Recorder ON").

Deploy
This command starts autonomous data collection, putting the ADP into deployment mode (see section 3.1). The ADP first saves all recently entered commands (commands will not be lost if a "SaveSetup" is not done prior to starting data collection). When using the deploy command, data collection will begin when the ADP clock reaches the specified Start Date and Time. If the current date and time is after the specified start date and time, data collection will begin immediately. When in deployment mode, ADP data are always stored to the recorder regardless of the recorder setting and the system will always enter a reduced power state if there is sufficient time between profiles ("AutoSleep" is forced ON).

Test
This performs a built-in test of all major ADP functions. These include CPU and DSP operation, as well as compass and recorder operation (if installed). It displays individual results from each test. We suggest using this command when preparing for any autonomous deployment (see section 7.3).

SaveSetup
This command saves all current parameter settings to EEPROM. This must be done before the system is shut down (or before a BREAK is sent) or any recently entered commands will be lost. This is performed automatically as part of the "Start" and "Deploy" commands.

Defaults   (short command "DEF")
This sets all ADP parameters to their default values. See the individual command descriptions for default values.

Ver
This outputs the version number of the CPU firmware.

DSPVer
This outputs the version number of the DSP firmware.

BoardRev
This outputs the revision number of the ADP electronics boards.

SerNum
This command returns the instrument serial number from memory (should match the serial number stamped on the transducer head).

Date <yy/mm/dd>
When this command is given without argument, it returns the date from the ADP clock. When given a date in the form "yy/mm/dd" (where yy = year (2 or 4 digits), mm = month (2 digits), and dd = day (2 digits)), it resets the date in the computer clock. Example: "date 1995/09/08" or "date 95/09/08" are equivalent commands setting the date to September 8, 1995.

Time <hh:mm:ss>
When this command is given without argument, it returns the time from the ADP clock. When given a time in the form of "hh:mm:ss" (24-hour clock where hh = hour (2 digits), mm = minute (2 digits), and ss = seconds (2 digits)), it resets the time in the computer clock. Example: "time 16:24:08" sets the ADP time to 16:24:08 (4:24:08 p.m.).

PowerOff
This command puts the ADP into sleep mode, where power consumption is less than 1 mW. See section 3.1 for a description of sleep mode. We recommend placing the ADP in sleep mode whenever not in use (it will automatically enter sleep mode if left idle in command mode for more than 5 minutes).

AutoSleep ON | OFF   (short command "AS")
When this command is given without argument, it returns the current AutoSleep setting. This setting determines whether the ADP enters a reduced power state during data collection. If AutoSleep is ON, the ADP will enter this state when there is a period of at least 10 seconds when the ADP is not actively sampling (i.e. profile interval is 10 seconds greater than averaging interval). Power consumption is less than 1 mW in the reduced power state. If AutoSleep is OFF, the ADP electronics remain active even when not collecting data. The default setting is ON. In deployment mode, AutoSleep is forced ON.

OutFormat BINARY | ASCII   (short command "OF")
When this command is given without argument, it returns the current output format setting. This setting determines the format of data output over the serial port; either BINARY or ASCII. Data stored on the internal recorder are always stored in binary format. See section 3.14 for a description of output data formats. The default setting is ASCII.

OutMode AUTO | POLLED   (short command "OM")
When this command is given without argument, it returns the current output mode setting. This setting determines whether data are sent over the serial port immediately after the completion of a profile (AUTO), or only sent when a specific run time command is received (POLLED). The run time command "O" causes the output of the last mean profile from the buffer; see section 3.13 for a detailed description of run time commands. The default setting is AUTO.

Recorder ON | OFF
When given without an argument, this command returns the current recorder setting. When the recorder is ON, all data collected by the ADP will be stored on the internal recorder. When OFF, any data collected in data acquisition mode (i.e. using the "Start" command) will not be stored to the recorder (but will be output to the serial port). When in deployment mode (i.e. using the "Deploy" command), data are always stored on the internal recorder. The default setting is ON if a recorder is installed, or OFF if a recorder is not installed.

RecMode NORMAL | BUFFER
When this command is given without argument, it returns the current recorder mode setting. Recorder mode specifies what happens when all available space on the recorder is filled. If the recorder is in NORMAL mode, any data collected after the recorder is filled will be sent to the serial port but will not be stored on the internal recorder. In BUFFER mode, any data collected after the recorder is filled will overwrite the oldest data on the recorder. The default setting is NORMAL.

3.7.   Setup Commands

Setup commands affect the real-time data collection parameters of the ADP. These include temperature, salinity, number of depth cells, depth cell size, averaging interval, profile interval, and ping interval. The timing commands (averaging interval, profile interval, and ping interval) are also listed under deployment commands. In this section, each command is shown (with any command line options) in *Italics*. Short versions of these commands, if they exist, are shown in parenthesis on the same line.

Temp <d.d>
When this command is given without argument, it returns the current user-specified temperature. When given with an input argument in the appropriate range (-5.0°C < temperature < 50.0°C) it sets the user-specified temperature to this value. This temperature is for calculating sound speed if the temperature mode ("TempMode") is set to USER. Default setting is 20.0°C. See the ADP Principles of Operation for details on the effects of sound speed on ADP operation.

Sal <d.d>
When this command is given without argument, it returns the current user-specified salinity setting. When given with an input argument in the appropriate range (0 ppt <= salinity <= 60 ppt) it sets the salinity to this value. This salinity is for calculating sound speed. Default setting is 34.5 ppt. See the ADP Principles of Operation for details on the effects of sound speed on ADP operation.

Ncells <d>   (short command "NC")
When this command is given without argument, it returns the current number of depth cells recorded with each profile. When given with an appropriate input argument (integer 1-100) it sets the number of cells in each profile. Default setting depends upon acoustic frequency (see table below).

CellSize <d.d>   (short command "CS")
When this command is given without argument, it returns the current depth cell size (in meters). When given with a numerical argument in the appropriate range, it sets the depth cell size to this value. Depth cell size is specified in vertical distance from the ADP. The range and default values for cell size depend upon acoustic frequency (see table below).

BlankDistance <d.d>   (short command "BD")
When this command is given without argument, it returns the current blanking distance (in meters). When given with a numerical argument in the appropriate range, it sets the current blanking distance. The minimum blanking distance and default settings depend upon acoustic frequency (see table below).

The table below summarizes the default values for blanking distance, cell size, and number of cells for each ADP acoustic frequency.

ADP Profile Definition Variable Input Range and Default Values

Acoustic Frequency	Blanking Distance	Cells Size	Number of Cells
3.0 MHz	Range 0.2 - 2.0 m Default 0.2 m	Range 0.15 - 2.0 m Default 0.5 m	Range 1 – 100 Default 12
1.5 MHz	Range 0.4 - 4.0 m Default 0.4 m	Range 0.25 - 4.0 m Default 1.0 m	Range 1 – 100 Default 20
1.0 MHz	Range 0.5 - 6.0 m Default 0.5 m	Range 0.4 - 5.0 m Default 1.0 m	Range 1 – 100 Default 25
500 kHz	Range 1.0 - 12.0 m Default 1.0 m	Range 1.0 - 12.0 m Default 4.0 m	Range 1 – 100 Default 30
250 kHz	Range 1.5 - 20.0 m Default 1.5 m	Range 1.0 - 20.0 m Default 4.0 m	Range 1 – 100 Default 30

AvgInterval <d>   (short command "AI")
When this command is given without argument, it returns the current averaging interval (in seconds). When given with an integer argument, it sets the averaging interval to this value (in seconds). See the ADP Principles of Operation for the averaging interval required for a desired accuracy. The acceptable range of values is 1 to 43200; the default value is 120 seconds.

ProfileInterval <d>   (short command "PRI")
When this command is given without argument, it returns the current profile interval (in seconds). When given with an integer argument, it sets the profile interval to this value (in seconds). Profile interval is defined as the time between the start of successive profiles (see sections 1.2 and 1.3). The acceptable range is 1 to 43200 s; the default is 1200 s. Note that if averaging interval is greater than profile interval, averaging interval will take precedence.

PingInterval <d.d>   (short command "PGI")
When this command is given without argument, it returns the current ping interval setting (in seconds). See section 1.2 and 1.3 for a description of ping interval. When given with a numerical argument, it sets the minimum time between pings in a profile (in seconds). The acceptable range is 0.0 to 10.0 s; the default is 0.0 s. Settings of less than 0.5 s will cause the ADP to sample (ping) as rapidly as possible. Settings from 0.5 s to 10.0 s will set the minimum time between pings; within this range, ping rate is the inverse of ping interval. See the ADP Principles of Operation for details on the effect of ping rate on uncertainty in velocity data.

Ping interval is to reduce power consumption in environments where real variations in water velocity require long averaging intervals. Settings other than 0.0 seconds are uncommon and should only be selected by experienced users. See sections 7.1 and 7.2 for details about the power savings achieved using reduced pinging rates.

CoordSystem BEAM | XYZ | ENU   (short command "CY")
When this command is given without argument, it returns the current coordinate system setting. When given with an appropriate argument, it sets the coordinate system to this value. This affects the velocity data output to the serial port and stored to the internal recorder (if enabled). BEAM causes velocity data to be stored as along beam velocities. XYZ causes velocity data to

be recorded in the Cartesian coordinate system relative to the ADP. ENU causes the system to use the compass data to transfer velocity data to earth (east-north-up) coordinates. See section 4.3 and 6.3 for details on the different coordinate systems. The default setting is ENU. Settings other than ENU are selected only for specialized applications.

TempMode USER | MEASURED (short command "TM")
When this command is given without argument, it returns the current temperature mode setting. When given with an appropriate argument, it sets the temperature mode to this value. USER specifies that sound speed should be calculated from the user-input temperature. MEASURED specifies that sound speed should be calculated using data from the ADP temperature sensor. The default setting is MEASURED.

The standard ADP temperature sensor is sufficiently accurate and reliable (±0.2°C) for sound speed calculations. The most common reason for selecting a temperature mode of USER is to simplify post-processing corrections using data collected by other sensors. Note that sound speed is recorded with each profile, so post processing corrections are possible with either setting.

3.8. Deployment Commands

Deployment commands affect data collection parameters used for autonomous deployment. These include deployment name, averaging interval, profile interval, ping interval, start date and time, and burst sampling parameters. Note that several of the timing commands (averaging interval, profile interval, and ping interval) are also listed under setup commands. In this section, each command is shown (with any command line options) in *Italics*. Short versions of these commands, if they exist, are shown in parenthesis on the same line.

Deployment <name>
When this command is given without argument, it returns the current deployment name. When entered with an ASCII text input (no more than 5 letters or numbers) it sets the deployment name. This determines the file name under which data are stored to the internal recorder. All data from a single "Deploy" or "Start" command are stored in one data file. The file name on the recorder is the deployment name combined with a 3-digit number indicating the sequence of files under this deployment name. For example, if the deployment name is "LAKE" the data from the first "Deploy" or "Start" command will be stored in a file named "LAKE001". If data collection is stopped and re-started without changing deployment name, the file name will increment; i.e. "LAKE002" and "LAKE003". Default name is DEF.

Comments
This command allows the user to input comments that will be stored in the data file. There are three comment lines, each with a maximum of 60 characters.

StartDate <yy/mm/dd> (short command "SD")
When entered without an argument, this command returns the current deployment start date. When given with a date in the correct format (see "date" command), it sets the date on which data collection will begin. This date is used only in deployment mode (data collection started with the "Deploy" command). If the start date and time are before the current date and time, data collection will begin immediately. Default value is January 1, 1995.

StartTime <hh:mm:ss>   (short command "ST")
When given without an argument, this command returns the current deployment start time.
When given with a time in the correct format (see "time" command), it sets the time at which
data collection is to begin. This time is used only in the deployment mode (i.e. data collection
started with the "Deploy" command). If the start date and time are before the current date and
time, data collection will begin immediately. Default value is 00:00:00.

AvgInterval <d>   (short command "AI")
See description under setup commands (section 3.7).

ProfileInterval <d>   (short command "PRI")
See description under setup commands (section 3.7).

PingInterval <d.d>   (short command "PGI")
See description under setup commands (section 3.7).

BurstMode NO | YES   (short command "BM")
When given without an input argument, this command returns the current burst mode setting. An
input argument of NO disables the burst sampling mode. An input argument of YES enables the
burst sampling mode. See sections 1.2 and 1.3 for a description of burst sampling. Note that
burst sampling can only be used in deployment mode (data collection started with the "Deploy"
command). In data acquisition mode, this parameter is ignored. The default setting is NO.

BurstInterval <d>   (short command "BI")
When given without an input argument, this command returns the current burst interval (in
seconds). When entered with an integer argument, this sets the burst interval to this value (in
seconds). See sections 1.2 and 1.3 for a description of burst sampling. The acceptable range of
values is 1 to 43200 seconds. The default setting is 1200.

ProfilesPerBurst <d>   (short command "PPB")
When given without an input argument, this command returns the current number of profiles per
burst. When given with an integer argument, this sets the number of profiles per burst. See
sections 1.2 and 1.3 for a description of burst sampling. The acceptable range of values is 1 to
1000. The default setting is 1.

3.9. Recorder Commands

Recorder commands allow direct access to data stored in the ADP internal recorder. This
includes accessing files, checking recorder capacity, and extracting data. In this section, each
command is shown (with any command line options) in **Italics**. The motivation for the
abbreviated names is shown in parenthesis on the same line. The end of this section gives
examples of how recorder commands can be operated to access data.

Dir   (for directory)
List deployments currently stored on the recorder. Note that this command will take a few
seconds to scan the entire recorder.

LD   (for list deployments)
List deployments currently stored on the recorder. Note that this command will take a few
seconds to scan the entire recorder. Exactly the same as "Dir".

Format
Erase all data from the recorder card. Naturally, you should take some care before executing this command. Upon execution it will prompt for confirmation of erasing all data. The ADP will give an updated display showing progress in re-formatting the memory card (the process will take a few seconds).

RecStatus
Show the installed recorder size and the amount of free space remaining.

Recorder ON | OFF
See description under system commands (section 3.6).

RecMode NORMAL | BUFFER
See description under system commands (section 3.6).

OD <name>   (for open deployment)
When given an existing deployment name on the ADP recorder, this command allows access to data files within that deployment. A deployment must first be opened before any of the following recorder commands can be used. When first opened, the file marker is placed on the first profile in the specified data file (for retrieval using the RPA or RPB commands).

CD   (for current deployment)
Show what deployment is currently open.

RC   (for retrieve configuration)
Retrieve configuration and setup information from the currently open file. This includes all information in the file header that is stored only once per data file (same as retrieved by the software program GADPCTL – see the ADP Software Manual). The information is retrieved in a self-explanatory ASCII format.

RPA [N]   (for retrieve profile ASCII)
Retrieve N profiles from the current file in ASCII format. If N is not specified, one profile is retrieved. The first profile retrieved will be the one given by the file marker; after executing this command, this file marker will be moved to the profile immediately following the profiles just retrieved. The ADP will first send the profile header and then the profile data; see section 3.14 for a description of the output data format.

RPB [N]   (for retrieve profile binary)
Retrieve N profiles from the current file in BINARY format. If N is not specified, one profile is retrieved. The first profile retrieved will be the one given by the file marker; after executing this command, this file marker will be moved to the profile immediately following the profiles just retrieved. The ADP will first send the profile header and then the profile data; see section 3.14 for a description of the output data format.

FP   (for first profile)
Moves the file marker to the first profile in the file.

LP   (for last profile)
Moves the file marker to the last profile in the file.

GP <profile number>   (for go to profile)
Moves the file marker to the profile number given on the command line; this profile will be the next profile retrieved with the "RPA" or "RPB" commands.

CP   (for current profile)
Returns the number of the current profile shown by the file marker.

NP   (for number of profiles)
Returns the number of profiles in the currently open file (takes a few seconds to scan the file).

The following are examples of how to access recorder data from the direct command interface. The ADP software includes a program to download data files (SONREC – see the ADP Software Manual) and the direct access commands shown here are not needed for most applications.

Example 1: Retrieve configuration data from deployment LAKE001.ADP

LD	to list deployments;
OD LAKE001	to open the deployment;
RC	to retrieve configuration

Example 2: Retrieve the last 5 profiles in ASCII format from deployment LAKE001.ADP

LD	to list deployments;
OD LAKE001	to open deployment LAKE001.ADP;
NP	to retrieve the number of profiles (NP) recorder in the file (assume the ADP returns 1355 for this example);
GP 1351	to go to profile number 1351 in this file (fifth from the last profile);
RPA 5	to retrieve the last 5 profiles in ASCII format.

3.10. Sensor Commands

In normal ADP operation all commands to the optional sensors are handled automatically, and no direct commands need to be sent. These commands are provided for diagnostic purposes only.

Sensor
Display most recent temperature (°C), pressure (dbar), and battery voltage (V DC) data. Note that the battery voltage is measured after the voltage drop from an isolation diode, and thus will typically be 0.6-0.8 V lower than the voltage level input into the ADP.

Sensor CONT
Display continuous temperature (°C), pressure (dbar), and battery voltage (V DC) data. Note that the battery voltage is measured after the voltage drop from an isolation diode, and thus will typically be 0.6-0.8 V lower than the voltage level input into the ADP. Press any key to stop the output of sensor data.

PressOffset
Display the pressure sensor calibration offset value. See section 6.5 for details on the pressure sensor calibration constants.

PressScale
Display the pressure sensor calibration 1st order coefficient value. See section 6.5 for details on the pressure sensor calibration constants.

PressScale_2
Display the pressure sensor calibration 2nd order coefficient value. See section 6.5 for details on the pressure sensor calibration constants.

3.11. Compass Commands

In normal operation all commands to the compass are sent automatically and no direct commands need to be sent. The commands in this section are provided to assist in diagnosing problems and for greater flexibility in ADP operations. For a detailed description of the optional compass/tilt sensor, see SECTION 4.

Compass
Display most recent heading, pitch, and roll data from compass/tilt sensor. Data are output in a self-explanatory, ASCII text format.

Compass CONT
Display continuous heading, pitch, and roll data from compass/tilt sensor (updated twice per second). Data are output in a self-explanatory, ASCII text format. Press any key to stop data output and return to command mode.

Compass CAL
Perform a compass/tilt sensor calibration. This is done to account for ambient magnetic fields that will affect compass heading (typically caused by ferrous metals) and should be performed prior to any deployment. The ADP will output basic instructions for performing the calibration and provide a continuous display of heading, pitch, and roll. Press any key to terminate the calibration, view the calibration score, and return to command mode. (Refer to section 4.4 for more information about compass calibration and for details on interpreting the calibration score.)

3.12. Show Commands

There are 4 commands to display current ADP parameter settings, known as the "show" commands. Samples of these commands and their outputs are shown below. As is done throughout the manual, commands and responses to the ADP are shown in a different font (`courier`) and comments are set in the same font as the main portion of this manual (times new roman). For more information about individual command settings, see sections 3.6 through 3.8.

"Show Conf" displays the current ADP hardware configuration (see section 5.1 for more information about individual command settings).

```
>show conf

HARDWARE CONFIGURATION PARAMETERS
---------------------------------
Sensor serial # -------------- C18
Sensor type -- (kHz) --------- 1500
Number of beams -------------- 3
Beam Geometry ---------------- 3_BEAMS
Slant angle -- (deg) --------- 25.0
Orientation ------------------ DOWN
Compass/Tilt sensor ---------- YES
Recorder      sensor ---------- YES
Temperature  sensor ---------- YES
Pressure      sensor ---------- YES
PressOffset - (dbar) --------- -1.050000
PressScale -- (dbar/count) --- 0.000744
PressScale_2 (pdbar/count^2) -    153
External sensors ------------- NO
Paros pressure sensor -------- NO
Microcat CTD ----------------- NO
```

"Show system" displays the current system parameters.

```
>show system

CURRENT SYSTEM PARAMETERS
-------------------------
CPU Ver ---- ADP 5.3
DSP Ver ---- DSP 4.0
Board Rev. - REV D
Date ------- 1997/10/13
Time ------- 18:23:38
AutoSleep -- YES
OutFormat -- ASCII
OutMode ---- AUTO
Recorder --- ON
RecMode ---- NORMAL
```

"Show setup" displays the current data collection setup parameters.

```
>show setup

CURRENT ADP SETUP PARAMETERS
----------------------------
Temp ----------- (deg C) - 20.00
Sal ----------- (ppt) --- 34.50
TempMode ----------------- MEASURED
Sound Speed ---- (m/s) --- 1520.90
CellSize ------- (m) -----  1.00
BlankDistance -- (m) -----  0.40
Ncells ------------------ 20
AvgInterval ---- (s) ----- 120
ProfileInterval- (s) ----- 1200
PingInterval --- (s) ----- 0.0
CoordSystem ------------- ENU
```

"Show deploy" displays the current deployment parameters.

```
>show deploy

CURRENT DEPLOYMENT PARAMETERS
-----------------------------
Deployment ------------ LAPIZ
StartDate ------------- 1997/10/13
StartTime ------------- 20:00:00
AvgInterval ----- (s) - 120
ProfileInterval - (s) - 1200
PingInterval ---- (s) - 0.0
BurstMode ------------- DISABLED
BurstInterval --- (s) - 1200
ProfilesPerBurst ------ 1
Comments:
Buenos tardes, senor.  Como esta?
Muy bien, gracias.  Pero tengo mucho sed, amigo.
Si, claro.  Una cerveza, no?
```

3.13.   Run Time Commands

The commands shown here can be entered while the ADP is in data acquisition mode or deployment mode. These commands can be issued without causing any delay or interruption of data collection (except for a few milliseconds that the system spends in executing the command). The ADP will not respond if it is in the reduced power mode between profiles (i.e. if profile interval is greater than averaging interval). ADP responses to any of these commands may be delayed up to one second (this is the frequency at which the incoming command buffer is checked); allow for up to a 1 second delay after sending one of these commands.

These commands are provided to meet the needs of several specialized applications of the ADP, and are not needed by most ADP users.

+++
Sending three + characters in succession will cause the ADP to terminate data collection and return to the command mode. There is no time limit during which the characters must arrive. This command is provided as an alternative to sending a BREAK when relaying data over a modem (where sending a BREAK command may not be easily done).

O
At the end of each averaging interval the ADP places the profile in an output buffer in whatever format has been specified by the "OutFormat" command (BINARY or ASCII). If the "OutMode" command is set to AUTO, the ADP immediately transmits the contents of this buffer through the serial port. If "OutMode" is set to POLLED, the ADP continues normal data collection without transmitting the contents of the buffer.

In either output mode (AUTO or POLLED) the last mean profile remains in the output buffer until the next profile is completed. At this time, the contents of the buffer will be replaced with the new profile. At any time during data collection, the ADP can transmit the contents of the buffer. This is done by sending the character 'O' to the ADP through the serial port. This can be done as many times as desired without significantly affecting data collection, since the ADP uses only a few milliseconds of processing time to re-transmit the entire buffer. The output data format for both ASCII and BINARY is described in section 3.14.

Since the buffer is automatically updated at the end of each averaging interval, it is the responsibility of the user to request transmission of the buffer after each profile is collected, and before the averaging interval for the next profile is completed.

T
Sending the character T during data collection causes the ADP to output the current Date and Time in the ADP clock. The clock is read immediately before the date/time data are output, which can be up to 1 second after the T command is sent. The date/time output will in BINARY or ASCII format depending on the current setting of the OutFormat parameter.

In BINARY format, the following 10 bytes will be sent:

In ASCII format, the following line will be sent (using the standard ADP date and time format):

```
yyyy/mm/dd hh:mm:ss.hh   <CR> <LF>
```

Run Time Command "T" Binary Output Record

Field	Offset	Length	Description
Year	0	2	Four digit calendar year (i.e. 1995)
Month	2	1	
Day	3	1	
Hour	4	1	
Minute	5	1	
Second	6	1	
Hundredths	7	1	Hundredths of a second
CheckSum	8	2	2-byte CheckSum of preceding 8 bytes (see appendix 1 regarding Checksum calculation)

C+ and C
The C command is to steer the ADP clock. C+ advances the clock 1 second, C- sets the clock back 1 second. After a successful completion of this command the ADP will output the acknowledgment "OK <CR> <LF>".

N
Sending the character N during data collection causes the ADP to output the profile number of the last mean profile, the one currently in the output buffer. The number is output in either BINARY or ASCII format depending upon the setting of "OutFormat". In BINARY format, the following 6 bytes will be sent:

Run Time Command "N" Binary Output Record

Field	Offset	Length	Description
Profile number	0	4	Profile number as a 4 byte integer
CheckSum	4	2	2-byte CheckSum of preceding 4 bytes (see appendix 1 regarding Checksum calculation)

In ASCII format, the following line will be sent:

```
   <ProfileNumber> <CR> <LF>
```
Where <ProfileNumber> is an integer value without leading spaces.

A
Sending the character A during data collection causes the ADP to output the time left in the current averaging interval, in seconds. The number is output in either BINARY or ASCII format depending upon the setting of "OutFormat". In BINARY format, the following bytes will be sent:

Run Time Command "A" Binary Output Record

Field	Offset	Length	Description
Time left	0	4	Time left in seconds as a 4 byte integer
CheckSum	4	2	2-byte CheckSum of preceding 4 bytes (see appendix 1 regarding Checksum calculation)

In ASCII format, the following line will be sent:

```
<TimeLeft> <CR> <LF>
```

Where <TimeLeft> is an integer value without leading spaces.

3.14. Output Data Format

The ADP will output data over the serial port using either binary or ASCII format based on the setting of the system parameter "OutFormat". The setting of "OutFormat" affects only data sent to the serial port; data written to the internal recorder are always stored in binary format. The setting of "OutFormat" will affect the data sent to the serial port during data collection, data retrieved using the run time commands (see section 3.13), and the data extracted from the recorder using recorder commands (see section 3.9).

3.14.1.   Binary Data

Binary data files generated by the ADP, using either the real-time data collection software or the internal recorder, use the same format. See Appendix 1 for a detailed description of the ADP binary file format. Most of the binary structures output by the ADP over the serial port follow a format defined for the binary data file, and will refer to this appendix for a precise definition.

This section describes only the binary profile data output over the ADP serial port during data collection, using the run-time commands (see section 3.13), and using the recorder commands (see section 3.9). Each ADP profile is sent from the serial port as a single binary record as described below.

The exact size of each ADP profile record depends upon the hardware configuration (the number of acoustic beams - NB), the user configuration (the number of cells collected - NC), and whether the optional CTD/Bottom Track/SonWave options are installed. The basic layout of each profile record is shown in the table below. The following abbreviations are listed in this table.

ADP Profile Binary Data Structure

Field	Offset	Length	Description
Profile header	0	80	Profile header data
CTD data	80	16	CTD data (*if installed)
Bottom Track			Bottom Track data (*if installed)
Velocity	80 + (16*)	2*NB*NC	Velocity data
Standard deviation	80 +(16*) + 2*NB*NC	NB*NC	Standard deviation data
Signal amplitude	80 + (16*) + 3*NB*NC	NB*NC	Signal amplitude data
Pressure series			Pressure series (*if installed)
CheckSum	80 + (16*) + 4*NB*NC	2	2-byte CheckSum of preceding (80 + (16*) + 4*NB*NC) bytes

Each data type is defined in detail (using the C language structure definition) in Appendix 1. The list below shows the structures indicated for each data type.

- Profile header   [ProfileHdrType]
- CTD   [CtdType] (if present)
- BottomTrack   [BTrackType] (if enabled)
- Velocity   [ProfileData.Vel]
- Standard deviation   [ProfileData.VelStd]
- Signal amplitude   [ProfileData.Amp]
- Wave Header   [WaveHeaderType] (if enabled)
- Pressure time series   [WseriesType] (if enabled)

Appendix 1 also includes details on the calculation of the CheckSum sent with each binary profile record to ensure accurate data transmission.

3.14.2.   ASCII Data

When outputting ADP data over the serial port in ASCII format, there are two data output types. First is the hardware configuration and user setup parameters. This is output using the recorder command "RC" and contains all ADP hardware configuration settings (serial number, frequency, number of beams, etc.) and user setup parameters (cell size, number of cells, default temperature and salinity, etc.). The output is presented in a self-explanatory text format.

The second output type contains data from one ADP profile including the profile header, averaged velocity and standard deviation, signal amplitude data, CTD, Bottom Track and Pressure series data (if available). This is output over the serial port when each profile is collected and is also output using the recorder command "RPA" (see section 3.9). A sample of this output is shown below.

Regular Profile

```
Header1      16            C23             1 1997 10 15 10 49 53 3 1 1 2
Header1      30    100     40      60     400
Header1      1751    -10    -30    1879   2799    13     5      6      2      9   14931
Header1      0   0   0   0   67 200   66 200   24   21   24    0 161 231    0 117
```

OPTIONAL CTD data (if present)
```
             87514    468151          0    351354
```

OPTIONAL: Bottom Track data (if enabled)
```
             100    221     220     220     0     115    116    140 0
```

```
Cell  1      1      2     -22     -11   15   14    4 116 113 111
Cell  2      2     24     -13      -8   14   14    4 121 123 118
Cell  3      3     12       9      -4   13   14    4 114 114 110
             …
Cell  N      N      6      -4       0   13   12    4  65   71   61
```

OPTIONAL: Wave Record (if enabled)
```
Wave header    32 DEFAULT C23             1 1997 10 15 10 49 0 1 6 1 1 150
Pressure series  2000     2000     2000     2000     2000     2000
```

The information contained in the profile header (first four lines) is described below.

- Header Line 1:
  data type (internal use),
  system serial number ("c23"),
  profile number,
  6 values for profile time (year, month, day, hour, minute, second),
  number of beams (2, 3 or 4),
  orientation (0=down, 1=up, 2=side),
  temperature mode (0=user, 1=measured),
  coordinate system (0=beam, 1=xyz, 2=enu)

- Header Line 2:
  number of cells,
  cell size (in cm),
  blanking distance (in cm),
  averaging interval (in seconds),
  number of pings in this profile.

- Header Line 3:
  3 values for mean heading, pitch, and roll (in 0.1°)
  mean temperature (in 0.01°C)
  mean pressure (counts)
  3 values for standard deviation of heading, pitch and roll (in 0.1°)
  std temperature (in 0.01°)
  std pressure (counts),
  sound speed (in 0.1 m/s).

- Header Line 4: this line contains system variables relating to internal system operation; the last value on the line is measured battery voltage in units of 0.2 V (i.e. 117 = 23.4 V)

The format of the CTD, Bottom Track and Pressure series is documented in SECTION 8.

ADP ASCII Output Profile Data

Column #	Contents
1	Depth cell number
2	Velocity data (V1 or Vx or Veast) in mm/s
3	Velocity data (V2 or Vy or Vnorth) in mm/s
4	Velocity data (V3 or Vz or Vup) in mm/s
5	Standard deviation data (SD1 or SDx or SDeast) in mm/s
6	Standard deviation data (SD2 or SDy or SDnorth) in mm/s
7	Standard deviation data (SD3 or SDz or SDup) in mm/s
8	Amplitude (signal strength) data (beam 1) in counts (1 count = 0.43 dB)
9	Amplitude (signal strength) data (beam 2) in counts (1 count = 0.43 dB)
10	Amplitude (signal strength) data (beam 3) in counts (1 count = 0.43 dB)

SECTION 4.   Compass/Tilt Sensor

The ADP can be equipped with a compass and 2-axis tilt sensor to provide heading, pitch, and roll data. The sensor is the Precision Navigation TCM2. Compass data are to translate velocity from the instrument XYZ coordinate system to an Earth coordinate system (East-North-Up or ENU). For more information about the ENU coordinate system, see section 4.3.

While the TCM2 provides excellent quality data, there are some limitations to keep in mind. Most important is to be sure that the compass is correctly mounted for the orientation of the ADP (up- or down-looking), and that the installation matches the hardware switch settings (see section 5.5). See section 4.2 for details about compass installation and ADP orientation.

The compass includes a built-in calibration feature to account for the effects of ambient magnetic field (i.e. nearby ferrous metals). We recommend performing a compass calibration prior to each deployment. When properly calibrated, the compass provides heading accurate to ±2.0° and pitch and roll accurate to ±1.0° up to 50°. See section 4.4 for details about compass calibration.

Because the compass communicates with the ADP system through an RS-232 interface, it is possible for the user to communicate directly with the compass through the ADP. All communication with the compass is handled automatically by the ADP, and direct communication with the compass should not normally be necessary. For a discussion of how to communicate directly with the TCM2, see section 4.5.

4.1.   Testing Compass Operation

This section describes a simple procedure to verify compass operation using a continuous display of heading, pitch, and roll. The display can be obtained using the direct command interface or the compass calibration software. If using the direct command interface, the command "Compass CONT" gives a continuous output of heading, pitch, and roll (see section 3.11). The compass calibration software (COMPCAL, see the ADP Software Manual) provides a graphical display of compass data.

For this test, first start the display of compass data. Point the ADP X-axis (marked on the transducer head) towards each compass direction (North, South, East, and West) and compare the compass output with the expected reading. Test the pitch and roll sensors by tilting the ADP about the X-axis (roll) and Y-axis (pitch) respectively, and compare the output measurements with the estimated tilt angles.

For this test be sure that the compass is physically oriented up (which means the ADP will be oriented down if the compass is installed for down-looking operation) and the hardware orientation switches match the compass installation. Refer to section 4.2 for details about compass mounting and the definition of the compass coordinate system.

This test should be conducted in an area predominantly free of magnetic material. The data should appear reasonable within the accuracy of this type of experiment (±10° heading, ±5° tilt). Large errors or a lack of response indicate a problem with the compass. This is not intended as a precise test of compass accuracy, but a means to evaluate basic performance. For best results, we recommend performing a compass calibration prior to any deployment (see section 4.4).

4.2. Compass Installation and ADP Orientation

IMPORTANT: Whenever opening and closing the ADP, it is essential that the transducer head be correctly aligned. When correctly aligned, the ADP X-axis (as stamped on the transducer head) will point away from the underwater connector into the ADP housing. If the head is incorrectly aligned, compass data will be incorrectly interpreted and this will contaminate velocity data.

The ADP is configured at the factory for up or down-looking operation following user instructions. The user can determine the current configuration by using the "Show Conf" command from the direct command interface (see section 3.12). Both the installation of the compass and the setting of the hardware switches **must** be modified if the ADP is switched between up and down-looking operation. This section describes the compass installation; refer to section 5.5 regarding the hardware switch settings.

4.2.1. Compass Coordinate System

The critical part of compass installation is to maintain a known orientation relative to the acoustic transducers. This allows the ADP to use the compass data to translate velocity data from the XYZ coordinate system (relative to the ADP) to the ENU coordinate system.

Figure 2 illustrates the compass/tilt sensor layout and its XYZ coordinate system. **The compass must be operated with the component side facing upwards** (within the ±50° tilt limit); operation in any other orientation will result in invalid compass data and corrupted velocity data when using the ENU coordinate system (non-recoverable data loss).

The compass has a 10-pin connector at one end for communication with the ADP (using an RS232 interface). The positive X-axis is defined along the long axis of the compass board from the connector towards the magnetic coils. The positive Z-axis is defined perpendicular to the compass board, upwards from the side with the connector, coils, and tilt sensor. The positive Y-axis is defined for a right hand coordinate system.

Pitch is defined as a rotation about the Y-axis; positive pitch raises the magnetic coils above the connector. Roll is defined as a rotation about the X-axis; positive roll raises the magnetic coils above the tilt sensor.
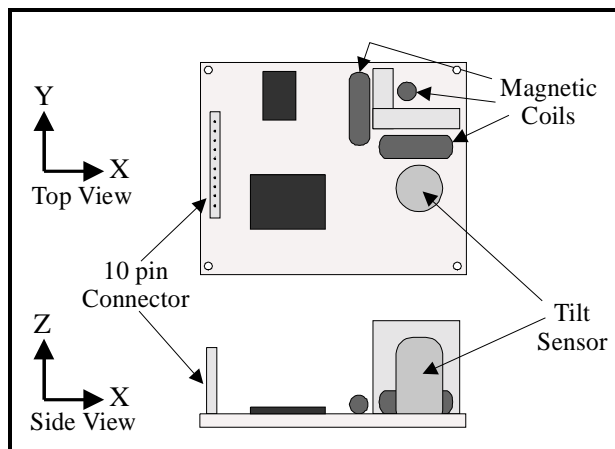

Figure 2– Compass Coordinate System

4.2.2. Up-Looking Compass Installation

Figure 3 illustrates the installation of the compass/tilt sensor for up-looking operation. The component side of the compass board is mounted away from the bottom of the ADP housing. This ensures that the compass is facing upward when the ADP is deployed looking up.

For up-looking operation, the compass is mounted directly to the threaded inserts on the bottom of the ADP housing (no additional standoffs are required). The inserts raise the compass 3/8" off the bottom of the housing. The positive Y-axis of the compass is aligned with the positive X-axis of the ADP. The positive X-axis of the compass is aligned 90° clockwise of the positive X-axis of the ADP.

When installing the compass, the board is secured using short #4-40 screws (spares are included in the ADP tool kit). Install fiber washers on both sides of the compass board for protection. It may be helpful to stick the washers to the compass board with a small amount of silicon grease before putting the compass into the housing (the o-ring grease in the ADP tool kit works well). The same grease can stick the #4-40 screws to the wrench when reaching into the canister. The compass mounting screws should be tightened securely but not over-tightened.
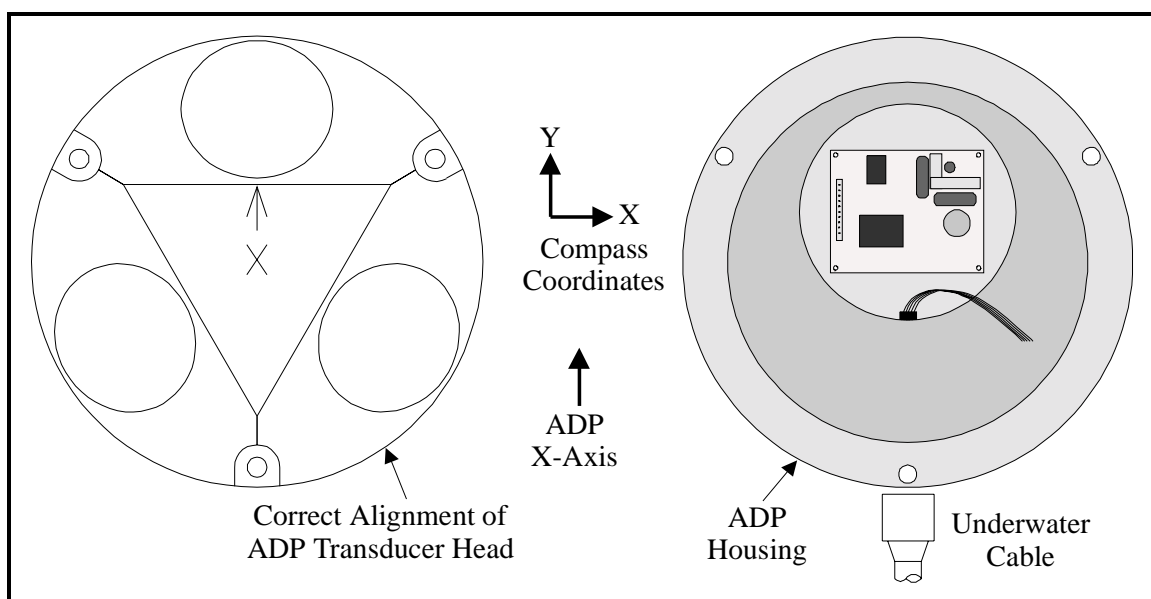

Figure 3 – ADP Up-Looking Compass Installation

When closing the ADP, be certain that the positive X-axis as marked on the transducer head is aligned as shown in Figure 3, and that the compass installation matches the desired deployment orientation and the sensor orientation as set in the ADP hardware switches (see section 5.5).

4.2.3. Down-Looking Compass Installation

Figure 4 illustrates the installation of the compass/tilt sensor for down-looking operation. The component side of the compass board is mounted towards the bottom of the ADP housing. This ensures that the compass is facing upward when the ADP is deployed looking down. Note that

compass components that are below the board (and hence are not directly visible when the compass is installed) are drawn with dashed lines in Figure 4.

For down-looking operation, a set of 1" hex standoffs (included in the ADP tool kit) must be installed onto the threaded inserts on the bottom of the ADP housing. This provides the necessary clearance to install the compass with the components facing down. These standoffs should be snugly screwed into the threaded inserts, but take care not to over-torque as this may strip the standoff threads.

For down-looking operation, the positive Y-axis of the compass should match the positive X-axis of the ADP. The positive X-axis of the compass is aligned 90° counter-clockwise of the ADP X-axis.

When installing the compass, the board is secured using short #4-40 screws (spares are included in the ADP tool kit). Install fiber washers on both sides of the compass board for protection. It may be helpful to stick the washers to the compass board with a small amount of silicon grease before putting the compass into the housing (the o-ring grease in the ADP tool kit works well). The same grease can stick the #4-40 screws to the wrench when reaching into the canister. The compass mounting screws should be tightened securely but not over-tightened.

When closing the ADP, be certain that the positive X-axis as marked on the transducer head is aligned as shown in Figure 4, and that the compass installation matches the desired deployment orientation and the sensor orientation as set in the ADP hardware switches (see section 5.5).

4.3. The ENU Coordinate System

The translation of velocity data from XYZ to Earth (ENU) coordinates is enabled or disabled through commands to the ADP and is transparent to the user. Selection of the coordinate system is done using the "CoordSystem" command (see section 3.7) or by a menu item in the data
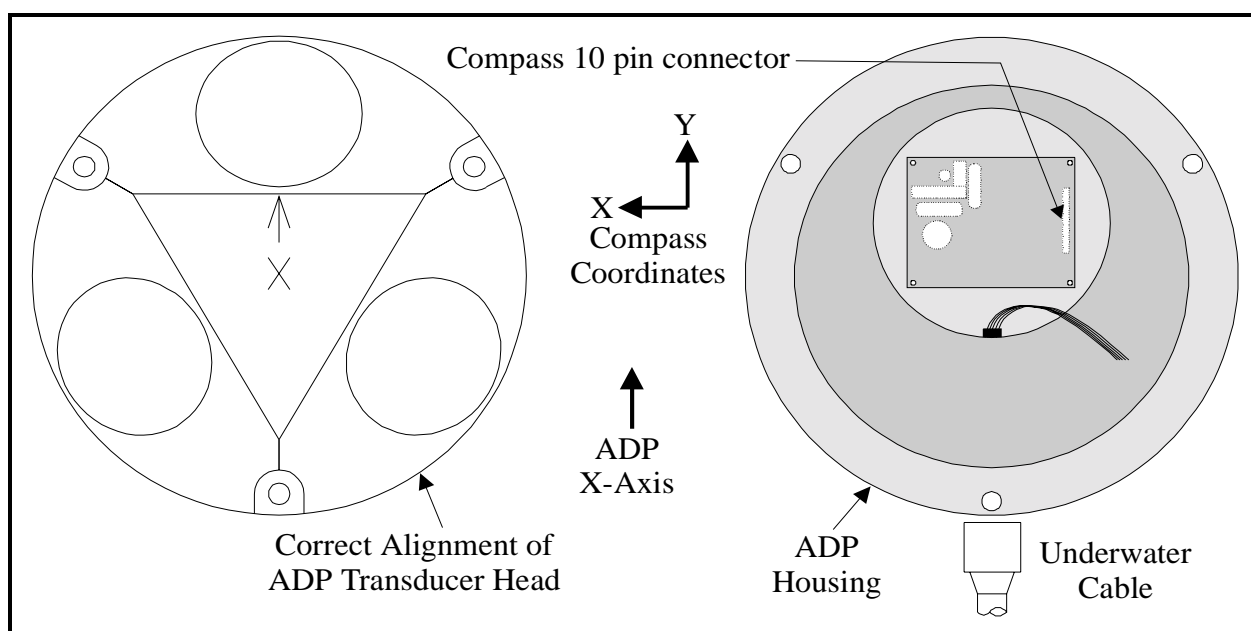

Figure 4 - Down-Looking Compass Installation

acquisition software (see the ADP Software Manual). When the compass is installed, data are stored with each profile regardless of the coordinate system setting.

When using the ENU coordinate system, velocity is reported in Earth coordinates regardless of the physical orientation of the ADP (within the operational limits of the compass). Consequently, an ADP that is mounted with variable orientation will provide velocity data consistent with the direction and speed of the water current itself, regardless of the orientation when measuring the current.

Additionally, velocity data in each profile are averaged using continually updated compass data. If the ADP changes orientation during a profile, velocity data will be averaged in Earth coordinates and will not be contaminated by instrument motion. Using any other coordinate system (BEAM or XYZ) eliminates this vector averaging and can contaminate data if the ADP moves during the course of an averaging interval. We recommend using the ENU coordinate system except for specialized applications.

4.4. Compass Calibration

The compass can be calibrated to compensate for ambient magnetic fields, which may cause errors in heading measurements. Magnetic distortion is most commonly caused by ferrous metal near the ADP. If the ADP is mounted on or near anything that contains magnetic material or generates a magnetic field, the compass should be calibrated prior to starting data collection. Additionally, the compass should be calibrated when moved to a different environment or mounting apparatus.

There are two methods for compass calibration. The first is to use the compass calibration software, described in the ADP Software Manual. Alternatively, the operator can use the compass commands from the direct command interface.

To begin a compass calibration using the compass commands, establish communication with the ADP. Type the command "compass cal" and press ENTER. The program will display necessary instructions for the calibration, and give a continually updated output of heading, pitch, and roll. The compass is now in multiple-point calibration mode and is collecting sample points. Rotate the compass slowly through 360 degrees at least twice, varying the pitch and roll as much as possible, so that a complete rotation takes at least one minute to complete. When this has been completed, press any key to terminate the calibration. The ADP will respond with a calibration score, which will look like the following.

```
H9V9M5.3:
```

The number following the 'H' and 'V' should be high (scale of 0 following the 'M' should be low (on a scale of 0 to 100). The number following the H reflects the quality of the horizontal calibration, the number following the V reflects the quality of the vertical calibration, and the number following the M reflect the amount of magnetic distortion present. While scores will vary, if either H or V is below 6, or if M is greater than 30.0, you should repeat the calibration. If the results do not improve, consider changing the location or modifying the mounting structure.

The compass calibration software follows an essentially identical procedure, and reports the same calibration score. (See the ADP Software Manual for details.)

4.5.   Communicating Directly with the Compass

All communication for compass operation is done automatically by the ADP; under normal circumstances, the user should not need to communicate directly with the compass. Should the need arise, the user can communicate with the compass through the ADP by establishing communication and bypassing the ADP processor for a direct link to the compass.

To communicate with the TCM2, place the ADP in command mode. Send the following command to establish a direct link with the compass.

```
> echo compass
```

If the compass is operating properly, it should be continuously sending data to the ADP, which will be redirected to the user. The data will look something like:

```
$C143.2P3.4R5.5T24.5*3f
$C142.2P3.4R5.5T24.5*3e
```

The compass will now accept direct commands. For details on communicating with the compass, or for a copy of the compass manual, contact SonTek. When communication with the compass is no longer desired, typing three plus signs in succession ("+++") or sending a BREAK will return the ADP to command mode.

SECTION 5.   ADP Hardware

5.1.   ADP Hardware Configuration Settings

The exact hardware configuration of the ADP depends upon the requirements of the application. ADP hardware configuration settings can be displayed using the "Show Conf" command from the direct command interface (see section 3.12). A sample output of this command is given below.

```
>show conf

HARDWARE CONFIGURATION PARAMETERS
--------------------------------
Sensor serial # -------------- C18
Sensor type -- (kHz) --------- 1500
Number of beams ------------- 3
Beam Geometry --------------- 3_BEAMS
Slant angle -- (deg) --------- 25.0
Orientation ----------------- DOWN
Compass/Tilt sensor ---------- YES
Recorder     sensor ---------- YES
Temperature  sensor ---------- YES
Pressure     sensor ---------- YES
PressOffset - (dbar) --------- -1.050000
PressScale -- (dbar/count) --- 0.000744
PressScale_2 (pdbar/count^2) -    153
External sensors ------------- NO
Paros pressure sensor -------- NO
Microcat CTD ---------------- NO
```

A brief description of each of these parameters and possible settings is given below.

- Sensor serial number: The ADP serial number is stamped on the transducer head.
- Sensor type: This specifies the acoustic frequency of the ADP in kHz (3000, 1500, 1000, 750, 500, or 250).
- Number of beams / Beam geometry: Most ADPs use 3 beams for vertical profiling. Horizontal current profiling can be done using 2 beam systems. Specialized applications will use 4 beam systems in several different configurations (3+1 vertical, 4 Janus).
- Slant angle: The mounting angle (off vertical) of the ADP transducers (25° is standard).
- Orientation: Profiling orientation of the system for up-looking, down-looking, or side-looking operation. Note that this setting must match the compass installation for correct operation (see section 4.2). Also note that the orientation will affect the definition of the XYZ coordinate system (see section 6.3).
- Compass/tilt / Recorder / Temperature / Pressure sensor: These settings specify which optional sensors have been installed (see section 5.5).
- PressOffset / PressScale / PressScale_2: Factory calibration parameters for the optional pressure sensor (see section 6.5 for details).
- External / Paros pressure / Microcat CTD sensors: These settings specify the status of a number of optional external sensors that can be integrated with the ADP (see section 8.2 for details).

5.2.   ADP Internal Electronics and Wiring Overview

Stand-Alone ADP

The Stand-Alone ADP is our most popular configuration where the processor, recorder (optional), compass/tilt sensor, and pressure sensor (optional) are all housed in a single underwater canister. Figure 5 illustrates the internal mounting of the Stand-Alone ADP. All electronics except the compass/tilt sensor are mounted to the transducer head; the compass/tilt sensor is mounted to the bottom of the ADP housing as described in section 4.2.

The (circular) receiver board is mounted on three standoffs directly to the transducer head. Above the receiver board is the internal mounting hardware (all made of anodized aluminum), which consists of a circular plate above the receiver board with a rectangular plate attached at a right angle. The ADP processor is mounted on standoffs from the rectangular plate. If the ADP includes an internal recorder, a small right angle bracket is to keep the PCMCIA recorder card from being accidentally shaken loose. If the ADP includes a pressure sensor, a small electronics board for this sensor is mounted opposite the ADP processor.
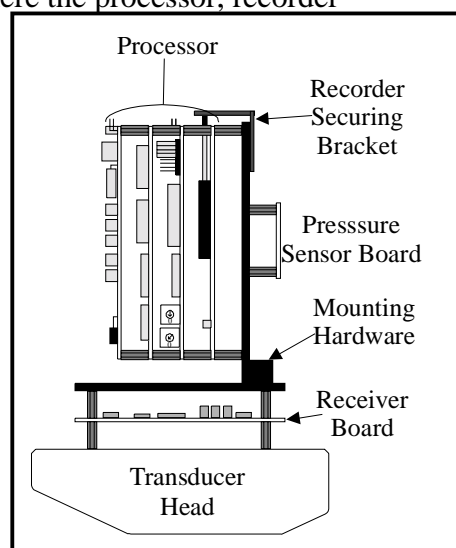

Figure 5

The ADP transducers are wired directly to the receiver board. The temperature sensor is connected to the receiver board using a red 2-pin connector. Two connectors on the receiver board (a 3-pin red and a 10-pin black) connect through a wiring harness to the ADP processor. The pressure sensor board connects at one side to the pressure sensor (mounted in the transducer head) and at the other side to a connector on the ADP processor. The ADP processor also has connectors to the compass/tilt sensor, and for external power and serial communication.

The Stand-Alone ADP also includes a grounding wire connected from one standoff on the receiver board to the housing. This establishes electrical conductivity between the two housings, and thus ensures that both the transducer head and housing are corrosion protected by the same zinc anodes.

For more details on the wiring of the ADP processor, see the complete processor description in section 5.3.

Low Profile ADP

In the low profile ADP, the transducer head housing includes only the receiver board, compass/tilt, and pressure sensor board (optional). The processing electronics are installed in a separate splash-proof housing (non-submersible). The transducer head and processor are connected using a custom-shielded cable up to 60 m long.

The receiver board is mounted as shown in Figure 5; the compass/tilt sensor is mounted directly to the housing as described in section 4.2. The pressure sensor board, if included, is mounted on a circular plate above the receiver board. As with the Stand-Alone ADP, the transducers are wired directly to the receiver board and the temperature sensor is connected to the receiver board

using a red 2-pin connector. All wiring from the receiver board and the compass/tilt sensor connect directly to the underwater connector on the housing. The pressure sensor board connects on one side to the pressure sensor (in the transducer head) and on the other side to the underwater connector.

The low profile ADP also includes a grounding wire connected from one standoff on the receiver board to the housing. This establishes electrical conductivity between the two housings, and thus ensures that both the transducer head and housing are corrosion protected by the same zinc anodes.

5.3.   ADP Processor

The ADP processor consists of three printed circuit (PC) boards with an optional fourth board for the internal recorder. The internal recorder is available only with the Stand-Alone ADP, and not with the low profile ADP.

Figure 6 illustrates the general layout of the ADP processor. The processing module consists of three printed circuit (PC) boards, with an optional fourth board for internal recording. These boards are connected in a vertical stack using connectors at one or both ends of the boards. From the top, they are called the analog board, the DSP board, the CPU board,

Figure 6 – ADP Processor

and the recorder board. The name and revision level of each board is shown in white lettering along one edge. The rectangular board dimensions are 10.1 x 15.2 cm (4 x 6 in), and within the stack each board is separated by 1.3 cm (0.5 in).
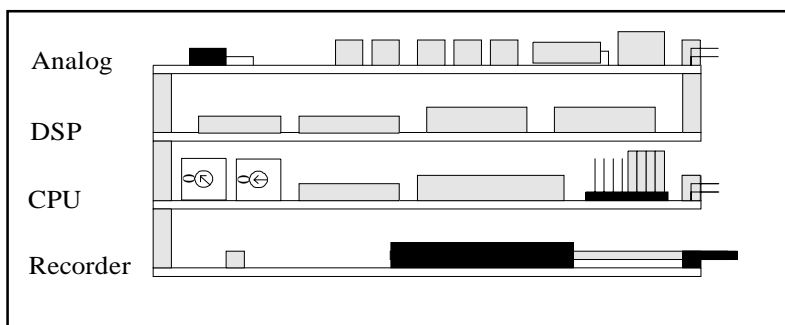
There are three places in the ADP processing module where hardware settings affect system operation. A set of switches on the analog board determines ADP profiling orientation and what additional sensors are installed (see section 5.5). Two hex rotary switches on the CPU are to set the communication baud rate and the address for RS485 communication (see section 5.6). Lastly, a set of jumpers on the CPU board determines whether the ADP uses RS232 or RS422 serial communication protocol (see section 5.7). See section 5.8 for instructions on accessing the processor.

A general description of the function of each board, along with the board layout and the location of important components are given below. The following sections also describe the connectors on each board and their function.

Analog board

Figure 7 shows the layout of the ADP analog board with a number of important features labeled. The analog board generates the acoustic transmit signals, receives the high frequency return signals, and performs the preliminary signal conditioning before the return signal is sent to the DSP board. The important features of the analog board are discussed below.
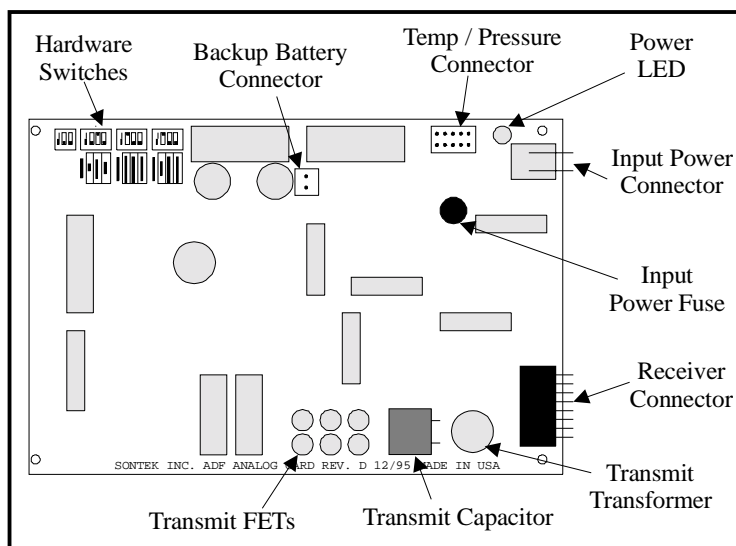

Figure 7 – ADP Analog Board

- Hardware switches - there are several sets of switches in the upper left corner of the board that determine ADP orientation and which optional components are installed (compass, recorder, temperature, and pressure). Refer to section 5.5 for details on setting these switches.)

- Temperature / Pressure connector - The 10-pin black connector in the upper right portion of the board receives signals from the temperature and pressure sensors. This connector is not keyed, so be sure to make note of its orientation before removing. The cable from this connector should lead to the receiver board, and to the pressure sensor board (if installed).

- Backup battery connector - The 2-pin red connector near the top center of the board is wired to a backup battery for the system clock. The connector is keyed and can only be installed in one direction.

- Power LED - The LED in the upper right corner will light if the ADP electronics has at least 12 V at the input power connector.

- Power connector - The 2-pin red connector in the upper right corner accepts DC input power (12-24 V). The polarity for each pin is labeled on the analog board. The mating connector is keyed and can only be installed in one direction. The cable from this connector will lead either to the input power connector (processor in the splash-proof housing for the Low Profile ADP) or to the underwater connector on the housing (Stand-Alone ADP).

- Input power fuse - The input power fuse is a black, cylindrical plug-in fuse (about 0.5 cm / 0.25 in diameter) located near the input power connector. The fuse is 3.15 A; 250 V. The fuse can be tested by lifting out of the socket and checking for continuity between the pins. Spare fuses are included in the ADP tool kit. The fuse should never be blown in normal operation, so a blown fuse may be an indicator of some other problem.

- Receiver connector - The black, 16-pin rectangular connector in the bottom right corner carries high frequency analog signals to and from the ADP receiver board. These signals are highly sensitive to noise; the cables and connectors should not be modified without contacting SonTek. The connector is keyed and can only be installed in one direction. For the Stand-Alone ADP, the cable from this connector will lead directly to the receiver board. For the ADP processor in the splash-proof housing, this connector is wired to the DB25 connector on the front end plate.

DSP board

Figure 8 shows the layout of the ADP DSP board with a number of important features labeled. The DSP board digitizes the return signal and performs Doppler calculations to determine velocity. The important features of the DSP board are discussed below.
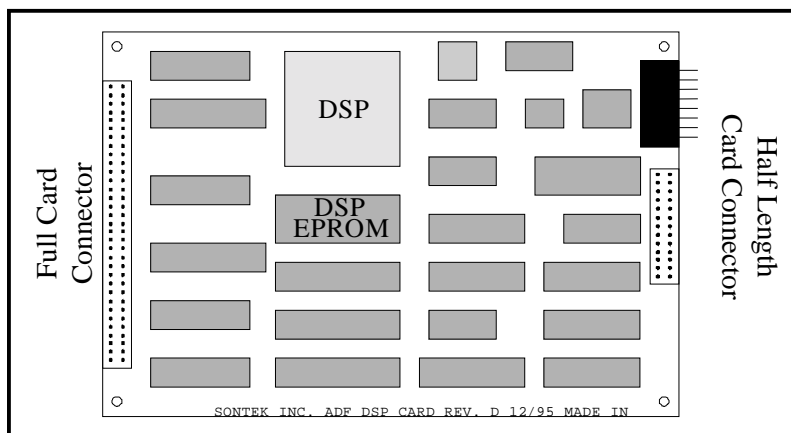

Figure 8 – ADP DSP Board

- DSP - The digital signal processing (DSP) chip provides the major computational power of the ADP processor.
- DSP EPROM - This EPROM stores the digital processing algorithms used by the ADP to measure velocity. Upgrades for this EPROM may be available periodically. To change the EPROM, use a small flat blade screwdriver to carefully remove the old EPROM. Be certain to align the half circle on the new chip with the identical mark on the processor board. Take care when installing the chip that all pins are intact and securely connected.
- The 16-pin, black rectangular connector in the upper right portion of the board is not used by the ADP.
- Half length card connector - The half length card connector (26 pins) on the right side of the board mates above to a connector on the bottom of the analog board.
- Full length card connector - The full length card connector (64 pins) on the left side of the board mates above to a connector on the bottom of the analog board, and below to a connector on the CPU board.

CPU board

Figure 9 shows the layout of the ADP CPU board with a number of important features labeled. The CPU provides the overall control of ADP operation including data collection, user interface, compass, and recorder control. The important features of the CPU board are discussed below.

- CPU - The central processing unit (CPU) chip controls all major ADP functions including data collection, user interface, compass, and recorder.
- CPU EPROM - The CPU EPROM stores the algorithms to control ADP operation. Upgrades for this EPROM may be available periodically. To change the EPROM, use a small flat blade screwdriver to carefully remove the old EPROM. Be certain to align the half circle on the new chip with the identical mark on the DSP board. Take care when installing the chip that all pins are intact, not bent and securely connected.
- Compass connector - The 10-pin red connector in the upper right portion of the board carries power and serial communication to and from the compass/tilt sensor. The connector is keyed and can only be installed in one direction. For the Stand-Alone ADP, the cable from this connector should lead directly to the compass. For the ADP processor in the splash-proof housing, the cable from the connector should lead to the DB25 connector on the front end plate.
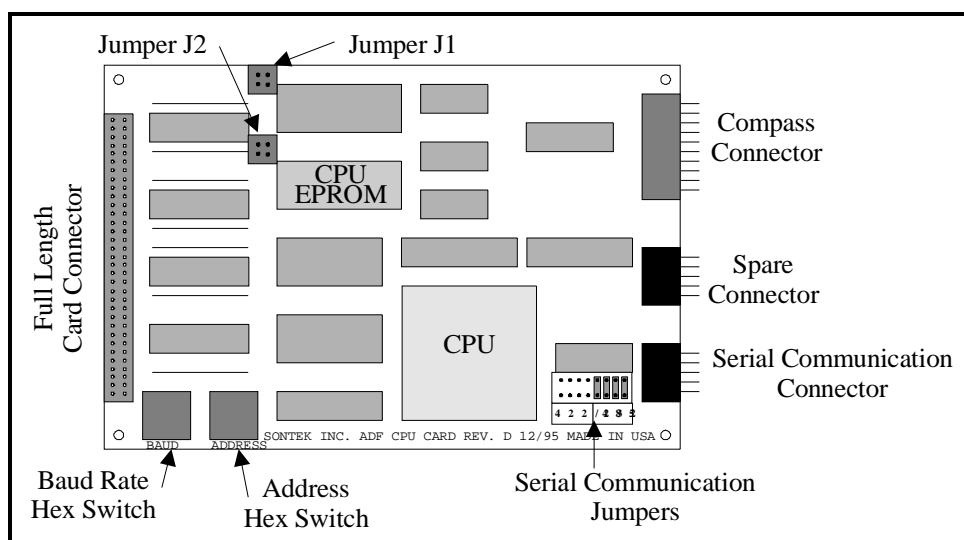
Figure 9 – ADP CPU Board

- Spare connector - The 10-pin, black rectangular connector in the right center portion of the board is not used.
- Serial communication connector - The 10-pin, black rectangular connector in the lower right corner of the board carries the serial communication signals for the external user interface. This is the same connector type as the spare connector listed above. The connector is keyed and can only be installed in one direction. For the Stand-Alone ADP, the cable from this connector should lead to the underwater connector on the housing. For the ADP processor in the splash-proof housing, the cable from this connector should lead to the DB9 serial communication connector on the front end plate.
- Full length card connector - The full length card connector (64 pins) on the left side of the board mates above to a connector on the bottom of the DSP board, and below to a connector on the recorder board.
- Baud rate hex switch - This hex rotary switch is to set the serial communication baud rate. The default setting is 9600 baud (setting 3). The switch is positioned so that it can be accessed while the processing module is assembled (see section 5.6).
- Address hex switch - This hex rotary switch is to set the system address for RS485 communication. The default setting is 0 (when using for RS232 or RS422 communication). Refer to section 5.6 for details on switch settings.
- Serial communication jumpers - The jumpers located in the bottom right corner of the board select the serial communication protocol; the defaults setting is for RS232. The jumpers cannot be accessed while the processing module is assembled. Refer to section 5.7 for details on jumper settings.
- Jumpers J1 and J2 – Jumper J1 should be left open (no pins connected). Jumper J2 should have the left two pins connected (closest to the full length card connector).

Recorder board

Figure 10 shows the layout of the ADP recorder board with important features labeled. The optional recorder board is for internal data storage during autonomous deployment.

Card Release Switch

Full Length Card Connector

PCMCIA Flash Card

SONTEK INC. Recorder REV. B 11/96 MADE IN USA

Figure 10 – ADP Recorder Board

- PCMCIA flash card - The recorder uses this non-volatile memory for data storage. Recorder sizes from 10 to 80 Mbytes are available.
- Card release switch - This switch is to eject the PCMCIA card from its mounting fixture. When assembled, the card is physically secured using an external bracket. The card should not need to be removed during normal operation.
- Full length card connector - The full length card connector (64 pins) on the left side of the board mates above to a connector on the bottom of the CPU board.
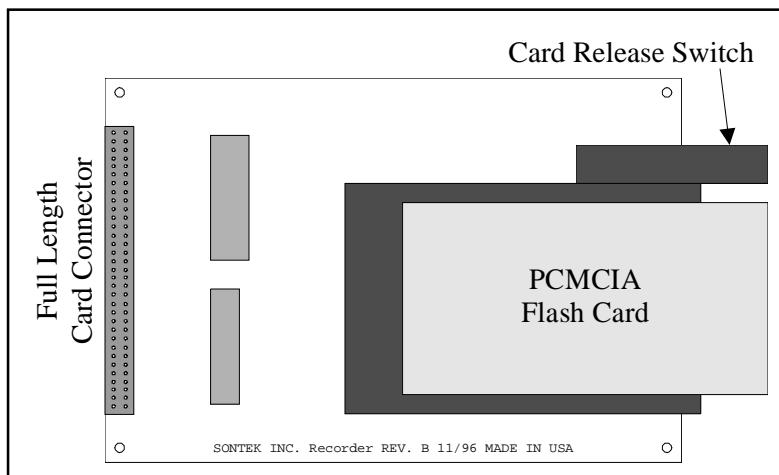
5.4. Cables and Connectors

The information in this section is intended to allow customers to construct their own cables for interfacing to the ADP. The ADP is supplied with all cables required for normal operations, but some applications (particularly with long cables) will require the user to build or purchase additional cables.

5.4.1. Stand-Alone ADP

The Stand-Alone ADP uses one external connector to supply DC power and serial communications. This is either an 8-pin or a 16- pin underwater mateable connector manufactured by Impulse Enterprises. Details on the connectors are given below.

Stand-Alone ADP Connector Type

Connector Type	Cable Connector Part Number	Bulkhead Connector Part Number (for info. only)
8 pin underwater mateable	IL-8-MP (with male locking sleeve)	BH-8-FS
16 pin underwater mateable	MIL-16-MP (with male locking sleeve)	MBH-16-FS

Impulse Enterprises manufactures all connectors and assembles all cables used by SonTek. Their address is given below.

Impulse Enterprises
8254 Ronson Road, San Diego, CA 92111, USA
Phone (619) 565-7050, Fax (619) 565-1649

The table below shows the pin out used for each connector type for RS232 and RS422 communication protocols. The wire colors shown are for the standard SonTek power and communication cable. Data transfer is listed relative to the ADP (Tx/Data Out refer to data being sent by the ADP, Rx/Data In refer to commands being received by the ADP).

Stand-Alone ADP Connector Wiring

IL-8-MP Pin number	MIL-16-MP Pin number	Wire color	RS232 function	RS422 function
1	1	Red	Vpower	Vpower
2	10	White	Data out	Tx+
3	11	Violet	Data in	Tx-
4	4 & 9	Drain	Drain	Drain
5	5	Yellow	Not used	Not used
6	6	Green	Not used	Rx+
7	14	Blue	Not used	Rx-
8	16	Black	Ground	Ground

When the ADP uses RS232 serial communication, the computer end of the power and communication cable is terminated with a DB9 connector for communication and a coaxial power plug for DC input power. The coaxial power connector accepts 12-24 V DC power input. The connector has the positive terminal on the inside and the negative terminal on the outside; it matches the output of the supply included with the ADP.

The DB9 connector follows the standard RS232 wiring protocol, as shown in the table below.

ADP Power and Communication Cable– DB9 Wiring

Pin #	Signal	Pin #	Signal	Pin #	Signal
1	Not used	4	Not used	7	Not used
2	Data Out	5	Ground	8	Not used
3	Data In	6	Not used	9	Not used

If the user has requested the system be setup for RS422 serial communication, the power and communication cable will replace the DB9 with a DB25 connector wired for RS422. Any ADP ordered with RS422 will also include a RS232/RS422 converter (which has DB25 connectors on each end) and a DB25 to DB9 converted cable; this allows the power and communication cable to be plugged directly into the serial communication port of any PC. Note that the RS232/RS422 converter includes a separate 12 V power supply that must be connected for the converter to work.

5.4.2. Splash-Proof Processor (Low Profile ADP)

The front of the ADP splash-proof housing has four connectors, a power switch, and a diode power light. The DB25 connector mates with the high-frequency cable from the ADP transducer head. The high-frequency cable is a custom shielded cable that is very sensitive to noise; neither the cable nor connector should be modified without contacting SonTek.

The coaxial power connector accepts 12-24 V DC power input. The connector has the positive terminal on the inside and the negative terminal on the outside; it matches the output of the supply included with the ADP. The diode on the front panel will light if the system is powered up and the power switch is on. The toggle switch on the splash-proof housing allows the system to be turned off and on when power is connected.

The DB9 connector provides access to the serial communication lines of the ADP. This connector has been wired following standard serial communication protocol. When using RS232, a simple pin-to-pin cable can connect the ADP to the DB9 serial port on a PC-compatible computer (a ribbon cable is provided with the system for this purpose). The table below gives the pin out for the DB9 connector.

Splash-Proof ADP Processor Housing DB9 Connector Wiring

Pin #	Signal	Pin #	Signal	Pin #	Signal
1	Rx-	4	Not used	7	Not used
2	Data Out / Tx+	5	Ground	8	Not used
3	Data In / Tx-	6	Not used	9	Rx+

The last connector on the splash-proof housing (a DB15) is not used by the ADP.

5.5.   Hardware Configuration Switches (Analog Board)

Figure 11 shows a diagram of the hardware configuration switches on the ADP analog board (see section 5.3 for a description of the ADP processing electronics; see section 5.8 for details on accessing the ADP electronics). The switches are divided into three sets of three. Placing any switch to the right is ON (logical "1"), and to the left is OFF (logical "0"). The switch settings shown in Figure 11 are for an upward looking ADP, with compass, temperature, and recorder installed; no pressure sensor is installed.

The first set of three switches defines ADP orientation. Only one of these switches should be ON at any given time. Switch #1 indicates that the system is deployed looking up (i.e. mounted on the bottom profiling up towards the surface). Switch #2 indicates that the system is looking down (i.e. mounted on the surface profiling down towards the bottom). Switch #3 indicates that the system has been deployed looking to the side (for 2 beam, 2D ADPs only).

Figure 11

IMPORTANT: When switching between up and down-looking, the user must set the correct switch and change the physical mounting of the compass (see section 4.2 for details on changing compass orientation).
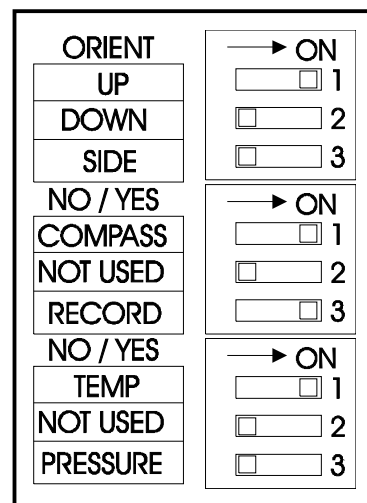
The second set of switches specifies which optional sensors have been installed. If switch #1 is ON, the system will look for the internal compass and tilt sensor. If the ADP cannot detect this sensor, it will return an error message when entering the command mode. Switch #2 is not currently used. Switch #3 indicates whether the internal recorder is installed.

The last set of switches specifies which of the analog sensors are installed. Switch #1 should be ON if the temperature sensor has been installed; all ADPs include temperature sensors. Switch #2 is not currently used. Switch #3 should be ON if the optional pressure sensor has been installed.

All switches are set to the appropriate value at the factory. The only settings that should be changed by the user are the orientation switches; these are changed whenever the user changes the ADP profiling orientation (up versus down-looking).

5.6. Baud Rate and Address Hex Rotary Switches (CPU Board)

Two hex rotary switches are mounted on the side of the CPU board; these switches can be accessed without disassembling the processor electronics. One switch is labeled "BAUD" and the other "ADDRESS". The switch labeled "BAUD" is to change the communication baud rate; settings are shown in the table below. The default setting is 9600 bps (setting 3). Use a small flat blade screwdriver to rotate the switch to the desired setting.

Baud Rate Hex Switch Settings (CPU Board)

Hex setting	Baud rate	Hex setting	Baud rate	Hex setting	Baud rate
0	1200	3	9600	6	57600
1	2400	4	19200	7	115200
2	4800	5	39400		

The second hex rotary switch, "ADDRESS", is intended for multiple system operation using RS485 protocol. RS485 operation is not covered in this manual. The ADDRESS switch should always be set to 0 for standard RS232 or RS422 operation.

5.7. Communication Protocol Jumpers (CPU board)

The ADP can use one of two serial communication protocols: RS232 (default) and RS422. RS232 is the standard protocol used by most computers; it is reliable over cable lengths to about 100 m. RS422 uses differential voltage levels to allow communications over longer cables (up to 1500 m). RS232/RS422 converters are available that let you run a RS422 system from the standard (RS232) serial port of a computer. Information for purchasing these converters is shown below.

B&B Electronics
707 Payton Rd.
Ottawa, IL 61350 USA
Phone (815) 434-0846
Fax (815) 434-7094
Converted Part # 422COR,
Power Supply Part # 422PS2

422/485	232		422/485	232

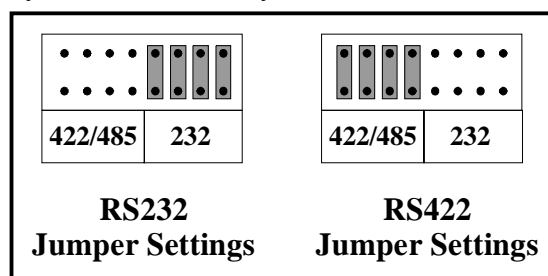**RS232 Jumper Settings**   **RS422 Jumper Settings**

Figure 12: Communication Protocol Jumpers

The communication protocol jumpers consist of eight 2-pin pairs. Figure 12 illustrates the jumper configuration for each communication protocol. To access the jumpers, the user must disassemble the processor (see section 5.8 for details). The ADP tool kit contains everything required for this task.

5.8. Accessing ADP Electronics

5.8.1. Stand-Alone ADP

Opening the sensor housing

To access the Stand-Alone ADP electronics use the following steps. Although the system can be opened and closed by one person, it may be helpful to have a second person available to help with the internal wiring of the ADP (particularly for the 250 and 500-kHz systems where the transducer head is notably heavier).

1. Whenever opening the ADP, work in a clean and static free environment.
2. Refer to section 5.1 for a description of the ADP electronics internal mounting.
3. Use the wrench and hex driver from the ADP tool kit to remove the three bolts holding the transducer head to the sensor housing. Extra mounting hardware is included in the tool kit; under normal conditions the hardware should not need to be replaced.
4. Lift the transducer head straight up from the sensor housing. While lifting the head, take care not to damage the following three things: the o-rings and o-ring surfaces, the connectors to the ADP electronics, and the ground wire to the sensor housing.
5. Disconnect the ground wire from the tab on the transducer head. Note that this tab may be somewhat difficult to disconnect; if it is, try rocking the connector back and forth to loosen it.
6. There are two connectors to the processing electronics: a black 10-pin connector (serial communication) to the CPU board and a red 2-pin (input power) connector to the analog board. Remove both of these connectors. Note that the power connector may be secured with a plastic wire tie; cut this prior to removing the connector.
7. Remove the transducer head (with attached electronics) and set on a static free surface.
8. While open, take care to protect all o-rings and o-ring surfaces from damage.

Closing the sensor housing

1. Before closing, check that all internal hardware is in place and secure. Verify that all connectors are correctly and securely installed.
2. Check that all hardware switches are correctly set, particularly for instrument orientation (see sections 4.2 and 5.5).
3. A desiccant bag is mounted near the ADP processor. Replace the desiccant if you suspect that it may be saturated. If practical, purge the ADP housing with a dry, inert gas (Nitrogen, Argon, etc.) prior to re-assembly.
4. Clean all o-rings and o-ring surfaces, and inspect for damage. Replace the o-rings if necessary (spare o-rings are included in the tool kit). Apply a thin layer of grease to the o-rings to hold them in place during assembly (a small amount of Dow Corning #111 Valve Lubricant and Sealant is included with the tool kit).

5. Re-connect the serial communication connector (black 10-pin) to the outside connector of the CPU board (see section 5.3 for the exact connector location).
6. Re-connect the power connector (red 2-pin) to the analog board. Secure with a small, plastic wire tie.
7. Connect the ground wire from the sensor housing to the tab on the transducer head.
8. Set the transducer head onto the housing, taking care that no wires are caught between the two surfaces.
9. **IMPORTANT**: Correctly align the ADP X-axis with respect to the canister. The X-axis as stamped on the transducer head should point away from the underwater connector on the sensor housing. For an illustration of this alignment, see sections 4.2.2 and 4.2.3.
10. Install the securing hardware. There should be plastic isolating sleeves on both the head and housing sides. Tighten the bolts to be snug, but do not over torque (tighten sufficiently to compress the lock washers).

Disassembling the processor

Following are instructions for disassembling the ADP processor. Note that the ADP internal mounting does not need to be removed from the transducer head to perform the following steps. When accessing the electronics, disassemble the system only as far as is necessary for the required maintenance.

1. Refer to section 5.3 for a detailed description of the ADP processor.
2. Whenever accessing the electronics, be sure to work in a clean, static safe environment to avoid damage to the system.
3. Disconnect the receiver board wiring harness from the black, 16-pin connector on the analog board. This connector is keyed and can only be installed in one direction.
4. Disconnect the temperature/pressure connector from the top of the analog board. This connector is not keyed, so be sure to note its alignment prior to removal. The tab on the connector should be placed towards the inside of the analog board.
5. Using the hex wrench from the ADP tool kit, remove the four screws (with flat and lock washers) from the corners of the analog board.
6. Carefully lift the analog board straight up from the DSP board. Note that it is connected to the DSP using edge connectors at each end. Take care not to bend the pins on these connectors during removal.
7. Use a ¼-inch wrench to remove the four standoffs securing the corners of the DSP board.
8. Carefully lift the DSP board straight up from the CPU board. Note that it is connected to the CPU using an edge connector at the end nearest the transducer head. Take care not to bend the pins on these connectors during removal.
9. Use a ¼-inch wrench to remove the four standoffs securing the corners of the CPU board.
10. Carefully lift the CPU board straight up from the recorder board. Note that it is connected to the recorder using an edge connector at the end nearest the transducer head. Take care not to bend the pins on these connectors during removal.
11. Use a ¼-inch wrench to remove the four standoffs securing the corners of the recorder board.
12. Lift the recorder board off the mounting hardware.

Assembling the processor

1. Place the recorder board so that the corners align with the four standoffs on the internal mounting frame. The board should be aligned so that the PCMCIA card is furthest from the transducer head.
2. Secure the recorder board at each corner with a standoff. Tighten securely, but do not over torque as this can damage the board.
3. Place the CPU board on top of the recorder board. Take care to align all pins on the edge connector; be certain that no pins are bent or damaged. Securely press the CPU board onto the recorder board so that the connector is fully seated.
4. Secure the CPU board at each corner with a standoff. Tighten securely, but do not over torque as this can damage the board.
5. Place the DSP board on top of the CPU board. Take care to align all pins on the edge connector; be certain that no pins are bent or damaged. Securely press the DSP board onto the CPU board so that the connector is fully seated.
6. Secure the DSP board at each corner with a standoff. Tighten securely, but do not over torque as this can damage the board.
7. Place the analog board on top of the DSP board. Note that these boards are joined by edge connectors at each end. Take care to align all pins on each connector; be certain that no pins are bent or damaged. Securely press the analog board onto the DSP board so that the connectors are fully seated.
8. Secure the analog board at each corner with a screw (with flat and lock washer). Place a small amount of blue locktite on each screw before installing. This will prevent screws from coming loose due to vibration (but will still allow the system to be disassembled later). Tighten securely, but do not over torque as this can damage the board.
9. Connect the temperature/pressure connector to the top of the analog board. This connector is not keyed, so be sure to maintain its original alignment. The tab on the connector should be placed towards the inside of the analog board.
10. Connect the receiver board wiring harness to the black, 16-pin connector on the analog board. This connector is keyed and can only be installed in one direction.

5.8.2. Low Profile ADP with Splash-Proof Processor

Opening the sensor housing

To access the Low Profile ADP sensor use the following steps. Although the system can be opened and closed by one person, it may be helpful to have a second person available to help with the internal wiring of the ADP (particularly for the 250 and 500-kHz systems where the transducer head is notably heavier).

1. Whenever opening the ADP, work in a clean and static free environment.
2. Use the wrench and hex driver from the ADP tool kit to remove the three bolts holding the transducer head to the sensor housing. Extra mounting hardware is included in the tool kit; under normal conditions the hardware should not need to be replaced.
3. Lift the transducer head straight up from the sensor housing. While lifting the head, take of the following three things: the o-rings and o-ring surfaces, the connectors to the ADP receiver board, and the ground wire to the sensor housing.

4. Disconnect the ground wire from the receiver board if necessary (the wire may be sufficiently long to allow access without removing this wire).
5. There are two connectors to the receiver board: a black 10-pin and a red 3 pin connector. Remove both of these connectors. Remove the transducer head (with attached electronics) and set on a static free surface.
6. While open, take care to protect all o-rings and o-ring surfaces from damage.

Closing the sensor housing

1. Before closing, check that all internal hardware is in place and secure. Verify that all connectors are correctly and securely installed.
2. A desiccant bag is mounted inside the housing. Replace the desiccant if you suspect that it may be saturated. If practical, purge the ADP housing with a dry, inert gas (Nitrogen, Argon, etc.) prior to re-assembly.
3. Clean all se and o-ring surfaces, and inspect for damage. Replace the o-rings if necessary (spare o-rings are included in the tool kit). Apply a thin layer of grease to the o-rings to hold them in place during assembly (a small amount of Dow Corning #111 Valve Lubricant and Sealant is included with the tool kit).
4. Re-connect the black 10-pin connector to the receiver board.
5. Re-connect the red 3-pin connector to the receiver board.
6. Connect the ground wire from the sensor housing to the receiver board, if it has been removed.
7. Set the transducer head onto the housing, taking care that no wires are caught between the two surfaces.
8. **IMPORTANT**: Correctly align the ADP X-axis with respect to the canister. The X-axis as stamped on the transducer head should point away from the underwater connector on the sensor housing. For an illustration of this alignment, see sections 4.2.2 and 4.2.3.
9. Install the securing hardware. There should be plastic isolating sleeves on both the head and housing sides. Tighten the bolts to be snug but do not over torque (tighten sufficiently to compress the lock washers).

Opening the splash-proof processor housing

1. Remove the four screws at each corner of the front end plate.
2. Lift the front end plate from the housing. The junction between the end plate and housing is sealed with a gasket (waterproof but not intended for submersion), so it may take some effort remove the plate; prying one edge up is a good way to start.
3. Pull the end plate straight out from the housing. A number of cables join the end plate to the electronics, and the electronics should slide smoothly out of the housing. Remove the electronics completely from the housing and place the end plate / electronics assembly in a static safe area.

Closing the splash-proof processor housing

1. Install the board stack (with end plate attached) by aligning the board edges with the extruded slots on the inside of the housing. The analog board should be the closest to the top of the housing. The boards should be installed such that the components on the analog board just clear the inside of the housing, while the pins on the bottom of the CPU board do not touch the housing at any point.
2. Align the end plate mounting holes to the four threaded inserts at each corner of the housing. Be sure that the sealing gasket is installed and in good condition.
3. Secure the end plate using the four #4-40 screws. Tighten securely but do not over torque as this can damage the threaded inserts.

Disassembling the processor

Following are instructions for disassembling the ADP processor. When accessing the electronics, disassemble the system only as far as is necessary for the required maintenance.

1. Refer to section 5.3 for a detailed description of the ADP processor.
2. Whenever accessing the electronics, be sure to work in a clean, static safe environment to avoid damage to the system.
3. Disconnect the black, 16-pin connector from the analog board. This connector is keyed and can only be installed in one direction.
4. Disconnect the temperature/pressure connector from the top of the analog board. This connector is not keyed, so be sure to note its alignment prior to removal. The tab on the connector should be placed towards the inside of the analog board.
5. Carefully lift the analog board straight up from the DSP board. Note that it is connected to the DSP using edge connectors at each end. Take care not to bend the pins on these connectors during removal.
6. Carefully lift the DSP board straight up from the CPU board. Note that it is connected to the CPU using an edge connector at the end nearest the transducer head. Take care not to bend the pins on these connectors during removal.

Assembling the processor

1. Place the DSP board on top of the CPU board. Take care to align all pins on the edge connector; be certain that no pins are bent or damaged. Securely press the DSP board onto the CPU board so that the connector is fully seated.
2. Place the analog board on top of the DSP board. Note that these boards are joined by edge connectors at each end. Take care to align all pins on each connector; be certain that no pins are bent or damaged. Securely press the analog board onto the DSP board so that the connectors are fully seated.
3. Connect the temperature/pressure connector to the top of the analog board. This connector is not keyed, so be sure to maintain its original alignment. The tab on the connector should be placed towards the inside of the analog board.
4. Connect the black, 16-pin connector to the analog board. This connector is keyed and can only be installed in one direction.

5.8.3. *Replacing ADP Processor EPROMs*

Periodically, there may be an upgrade available for either EPROM (CPU or DSP) in the ADP processor. These upgrades can either be installed by the user, or the system can be sent to SonTek to install the upgrade. Whenever an upgrade is installed at SonTek, a complete test of the system will be performed to verify all aspects of ADP performance.

1. Perform the upgrade in a clean, static-safe environment.
2. Follow the instructions in sections 5.8.1 and 5.8.2 to open the ADP housing and disassemble the processor card stack.
3. Locate the EPROM to be changed on either the CPU or DSP board; refer to section 5.3 to find the appropriate chip.
4. Remove the old EPROM using a small flat blade screw drive. Carefully lift up each edge of the EPROM until you can lift the chip up by hand. Set the old chip aside in a safe location until you have verified system operation with the new chip.
5. Install the new chip into the appropriate socket. Align the half circle on the chip with the half circle on the socket and on the board. Take care not to damage or bend any pins while installing the chip. Seat the chip securely into the socket with your fingers.
6. Follow the instructions in sections 5.8.1 or 5.8.2 to assemble the processor card stack and close the ADP housing.
7. Establish communication with the system and verify that you can start data collection before discarding the old EPROM.

5.9. Battery Pack Access and Installation

This section discusses accessing and replacing battery packs in the external battery housing. ADP battery packs, either alkaline or lithium, consist of 36 D-cell batteries welded together. Alkaline battery packs are wired to provide a nominal 18 V output, while lithium packs provide 21.6 V. Refer to Appendix 2 for details about battery pack construction.

The external ADP battery housing is constructed from PVC and is designed to hold three battery packs. The bottom end cap is permanently attached. The top end cap, with the 2-pin underwater mateable connector, screws into the housing and is sealed with a face seal o-ring. The battery housing is rated for deployment depths to 200 m. Internally, the battery packs are held in place using compressive foam pads and a retaining ring.

Opening the battery housing.

1. Vent off any differential pressure within the housing by loosening (or removing) the vent screw on the top end cap.
2. To remove the cap, turn the cap counterclockwise while holding the housing still.
3. If more leverage is needed, insert steel dowel pins (included with the ADP tool kit) into the holes on the end cap. Use a bar wedged between the pins as a lever arm to loosen the cap. Tapping lightly with a hammer on this bar while holding the cylinder will loosen the cap.
4. Once started, the cap should turn easily.
5. Upon removal of the cap, disconnect the wires to the battery packs and place the cap in a suitable location, which will protect the o-ring groove and threads from damage.
6. Ensure the o-ring seating surface on the housing is protected from mechanical damage while the cap is removed.

Closing the battery housing

1. Clean the o-rings and o-ring surfaces, and inspect for damage. Replace the o-rings if necessary (spare o-rings are included in the tool kit). Apply a thin layer of grease or the o-rings to hold in place during assembly (a small amount of Dow Corning #111 Valve Lubricant and Sealant is included with the tool kit).
2. Connect the battery pack leads to the connectors on the battery cap.
3. Ensuring that the o-ring seating surface on the housing is protected from mechanical damage, place the cap on the housing.
4. Rotate the cap counterclockwise 1-2 turns. This will help to align the threads on the cap with the threads in the housing and prevent cross threading.
5. Tighten the cap (clockwise) with your hands as far as possible.
6. Place the two dowel pins in the holes provided in the cap. Tighten further by using a bar between the dowel pins as a lever. Tighten the cap until it has bottomed out on the housing; this is sufficient to ensure the o-ring seal is in place. Do not over torque as this will make the housing difficult to open in the future.
7. Ensure the vent screw is tightened.

Battery pack removal

1. Use a large flat bladed screwdriver to lift the notched end of the retaining ring away from the housing wall. With the other hand, insert a small flat blade screwdriver between the retaining ring and the retaining plate. Lift the retaining ring up towards the top of the housing.
2. After removing one end of the retaining ring from the groove, the entire ring can be removed using a spiraling motion. Take care to avoid damage to the thread and o-ring surfaces while removing the retaining ring.
3. Remove the retaining plate and cushioning pads from the top of the battery packs.
4. Remove each battery pack using the Velcro handle provided.

Battery pack installation

1. Place one cushioning pad on the bottom of the housing before installing any battery packs.
2. Place the three packs into the housing on top of one another. During installation, align the wires from each back along the same side of the housing.
3. Place a number of cushioning pads on top of the upper battery pack. The pads should be slightly above the retaining ring groove (1-2 cm / 0.5-1.0 in).
4. Feed the battery leads through the large hole in the retaining plate and compress the cushioning pads with the battery cover until the retaining ring groove is exposed.
5. Insert the retaining ring into the retaining ring groove while keeping the retaining plate pressed down on the cushion pads. The ring will snap easily into place if pressed onto the retaining plate until the groove is exposed.
6. Ensure that the retaining ring is securely set into the groove around the entire diameter of the housing.
7. Check that the batteries are securely held in the housing by lifting the housing and gently shaking it from side to side.

<u>Spare parts kit</u>

The following parts relating to the battery housing are included with the ADP tool kit.

- 4 - ¼" x 1 ¾" stainless steel dowel pins
- 2 - 2-258 nitrile rubber o-ring
- O-ring silicon lubricant.

For information only: The retaining ring is a Spirolox UR-575 Retaining Ring, and the vent plug is a Parker 4 HP50N 316 Stainless Steel Plug.

SECTION 6.   Operational Considerations

6.1.   Power Supply and Real-time Clock Backup Battery

The ADP operates on 12-24 V DC input power. The exact power consumption varies with system frequency and user operating parameters, but is typically in the range from 1.5-3 W (see section 7.2). In sleep mode it consumes less than 1 mW. If the input voltage is less than 12 V, the ADP will not operate reliably. A supply voltage greater than 24 V can damage the ADP electronics. The ADP measures and stores the input voltage; this can be accessed from the direct command interface (see section 3.10) and the binary data files (see the ADP Software Manual).

When running the ADP from batteries, keep track of battery capacity to prevent the loss of data because of insufficient power. Note that the ADP internal recorder uses a solid state PCMCIA card for data storage and will not be affected if the batteries are drained. See section 7.2 for details about estimating power consumption and battery life.

The ADP also includes a backup battery (one lithium AA cell) to power the system clock when main power is unavailable. Under normal operating conditions, this battery can be expected to last for many years; however, we recommend replacing it every 2-3 years for safety. If the backup battery dies, the system clock will reset when main power is disconnected. The replacement battery should provide a minimum output voltage of 3.5 V.

Note that when the ADP power supply is cycled (turned off and on), it will enter whatever mode it was in previously (command mode, data acquisition mode, deployment mode). If the ADP was in sleep mode before cycling the input power, it will enter command mode. If the ADP was in deployment mode, on power up the ADP will enter deployment mode and begin data collection immediately (ignoring the start date and time settings). This is to avoid data loss in the event that the ADP clock is reset (see section 3.2).

6.2.   Mounting and Handling the Sensor

The ADP has been designed for easy mounting and deployment. The following is general advice to simplify deployment procedures and avoid instrument damage.

- All acoustic transducers must be completely submerged during data collection. Operating with the transducers out of water will not cause damage, but will result in meaningless data.
- When mounting the ADP near underwater obstructions (bridges, piers, lines, cables, etc.) take care that the acoustic beams will not see the obstructions. The ADP transducers generate acoustic beams where the majority of the energy is concentrated in a cone only a few degrees wide. The center axis of each beam is perpendicular to the face of the transducer; transducers are slanted 25° from the vertical. Although these beams are very narrow, obstructions near the beams may interfere with velocity measurements. Additionally, large obstructions will cause significant flow interference, which can have a major impact on velocity data. In general, we suggest that the ADP is deployed a distance of at least 2-3 times the water depth from any major underwater obstructions.
- With the exception of 2 beam systems (for horizontal profiling), the ADP is designed for vertical profiling either looking up or down. Deployments resulting in non-vertical profiling must be carefully considered, and are not encouraged.

- For most vertical profiling applications, the instrument should be as close to as level as possible (ideally within 10°). Although the tilt sensor can measure tilt angles to 50°, installation tilts of more than 15-20° may have a significant impact on velocity data.

There are three mounting holes on the bottom of the ADP housing, each aligned with one acoustic beam. The mounting holes are designed for use with 1/4" bolts with plastic screw isolators. The isolators protect the canister from damage and serve to electrically isolate the instrument from the mounting frame and bolts. Additional isolators are included in the ADP tool kit.
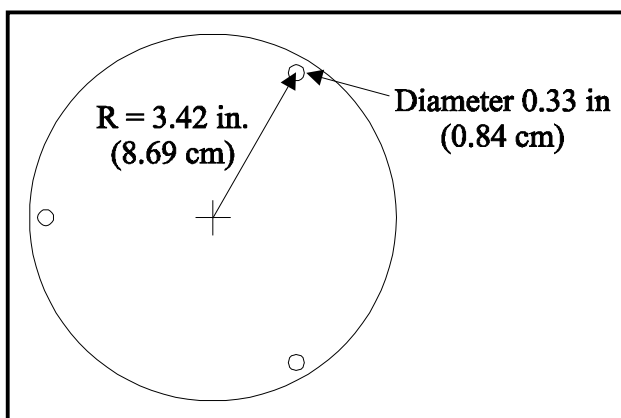
Figure 13 shows the bolt pattern for the mounting plate. The sensor can be mounted a variety of ways, but always be careful not to damage the transducers or the sensor housing. In all mounting operations, take care to provide protection for the underwater cable and connector. The cable and connector should never be used to raise or lower the ADP, or as a structural part of a mounting frame.

Figure 13 – ADP Mounting Bolt Pattern

When using the optional compass/tilt sensor, we do not recommend the use of magnetic material in the construction of the mounting frame. If magnetic material must be used, be sure to perform a compass calibration while the ADP is attached to the mounting frame to attempt to remove any interference in compass heading measurements (see section 4.4).

6.3. ADP Coordinate System

The ADP supports three coordinate systems for velocity data: ENU (East-North-Up), XYZ, and BEAM. The coordinate system setting is determined in the setup menu of the real-time software (see the ADP Software Manual) or using the "CoordSystem" command from the direct command interface (see section 3.7).

ENU (East-North-Up) coordinate system

For systems with the optional compass/tilt sensor, velocity can be recorded in ENU (East-North-Up) coordinates. Using the ENU coordinate system allows the ADP to report velocity data independent of instrument orientation (within limitations – see SECTION 4).

Using the ENU coordinate system also allows the ADP to vector average samples within each profile (using updated compass/tilt information); if ADP orientation changes during the averaging interval, velocity data will still reflect the true water velocity. When using the XYZ or BEAM coordinate system, velocity data can be corrupted if the ADP orientation changes during the averaging interval. SonTek recommends using the ENU coordinate system except for specialized applications by experienced users.

Whenever using the ENU coordinate system, or whenever recording data from the internal compass/tilt sensor, be sure that the compass installation matches the hardware orientation settings. See sections 4.2 and 5.5 for details.

XYZ coordinate system

When using the XYZ coordinate system, velocity measurements are stored using a right handed Cartesian coordinate system relative to the ADP. The positive X-axis is stamped into the transducer head for easy reference. When the transducer head has been properly installed, the X-axis should point away from the underwater connector on the ADP housing (see section 4.2).

The definition of the XYZ coordinate system depends upon the setting of the hardware orientation switch (see section 5.5). For up-looking operation, the positive Z-axis is defined as upwards along the axis of the sensor housing away from the transducer head. For down-looking operation, the positive Z-axis is defined along the axis of the sensor housing from the top of the transducer head into the housing. In both cases, the positive Z-axis is vertically up based upon the orientation of the system. The Y-axis is always defined from the X and Z-axes to give a right hand coordinate system.

Note that the alignment of the Y and Z-axes with respect to the ADP housing reverse depending on the ADP orientation.

For 2-beam side-looking systems, the positive Y-axis is defined along the axis of the sensor housing away from the transducer head. For a normal deployment orientation (with the cable from the sensor housing going vertically up), this results in the standard configuration of the positive Z-axis as vertically up (although 2 beam system measure velocity only in the XY plane).

BEAM coordinate system

When using the BEAM coordinate system, the ADP reports along beam velocity; positive velocity is away from the ADP, negative is towards the ADP. The X-axis stamped on the transducer head always points to beam number 1. If the ADP is placed on the floor with the transducer looking up (with the user looking down at the systems) the transducer are number clockwise from #1.

Beam numbering is identical for a 2-beam, 3-beam or 4-beam Janus configuration (clockwise from beam 1). For a 4-beam system with a vertical beam, the slanted beams are numbered 1-3 as described above and the vertical beam is number 4.

6.4. Serial Communication Protocol

The ADP supports RS232 and RS422 serial communication protocols. Switching between RS232 and RS422 changes the electrical interface and has no effect on the command interface of the ADV. The default setting is for RS232; this is the same protocol used by the standard serial ports on PC-compatible computers and is considered reliable for cable lengths to about 100 m.

RS422 communication uses differential voltage signals to increase immunity to external noise. This allows operation over longer cables; RS422 is considered reliable for cable lengths to 1500 m. RS232 to RS422 converters are available commercially and allow an ADP using RS422 communication to be connected to the RS232 serial port of a PC-compatible computer. One supplier for this type of converter is shown below.

B&B Electronics   Phone (815) 434-0846
707 Payton Rd.   Fax (815) 434-7094
Ottawa, IL 61350 USA
Converted Part # 422COR, Power Supply Part # 422PS2

Refer to section 5.7 for information on jumpers used to change the ADP serial communication protocol.

6.5. Temperature and Pressure Sensors

<u>Temperature sensor</u>

To measure temperature, the ADP uses a thermistor mounted on the inside of the transducer head. For systems constructed from plastic, the thermistor is mounted in a counter-bore hole on the inside of the transducer head very close to the exposed surface (to minimize the insulating effects of the plastic). The temperature sensor has a specified accuracy of ±0.1°C, which is more than sufficient for sound speed measurements (for details on the effects of sound speed, see the ADP Principles of Operation). Temperature data are sampled once per second during the averaging interval; mean and standard deviation of these samples are recorded with each profile.

<u>Pressure sensor</u>

If the optional strain gage pressure sensor is installed, it is mounted in a recessed hole on the top transducer head. The pressure sensor is connected to a small printed circuit board mounted on the back of the ADP processor (Stand-Alone ADP) or above the receiver board (Low Profile ADP). Outputs from the pressure sensor board are connected to the temperature/pressure connector on the ADP analog board (see sections 5.1 and 5.3 for details).

The pressure sensor is mounted in the ADP transducer head as pictured in Figure 14. The sensor is recessed and isolated from the water (for corrosion protection) by a diaphragm and silicon oil reservoir. The diaphragm is held in place by a plastic retaining plug that screws into the end cap. The pressure sensor forms a water tight seal using a bore seal o-ring. For added leak protection, the path into the ADP housing is filled with epoxy. Under normal

Figure 14

conditions, the user should not need to access the sensor directly. If you suspect problems, please contact SonTek before trying to access the sensor.
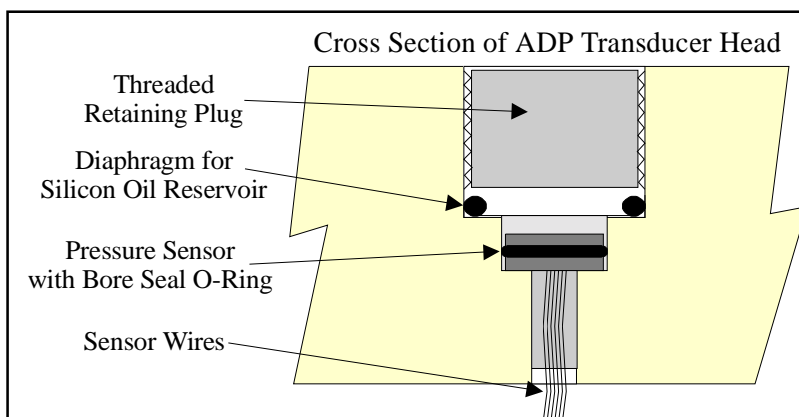
Data from the pressure sensor is sampled by the ADP electronics using a 12-bit A/D converter. Data is converted to a 2-byte integer scaling the A/D counts by 16 (giving a total count range of 0-65520, with a step size of 16 counts). Pressure data are stored in counts that must be converted to physical units (decibar) using three calibration constants. Pressure in counts is converted to decibar using the following formula.

```
dbar = PressOffset + (PressScale × Counts) + (PressScale_2 × (Counts²))
```

where

dbar = measured pressure (decibar)
PressOffset = offset calibration constant set at factory (decibar)
PressScale = linear (1st order) calibration constant set at factory (decibar/count)
PressScale_2 = quadratic (2nd order) calibration constant set at factory (decibar /count^2)
Counts = measured pressure (counts)

The values for PressOffset, PressScale and PressScale_2 can be accessed three ways: through the direct command interface (see section 3.10), from the data conversion software *.CTL file (see the ADV Software Manual), or directly from the binary data file. In the first two methods, PressOffset and PressScale are output with the units shown above and can be entered directly in the formula above. PressScale_2 is output with units of (10^{-12} decibar/count^2) and must be multiplied by (10^{-12}) before using in the above formula.

When using the binary data directly, each constant is stored as a long integer and must be converted to the appropriate units before using. PressOffset is stored in units of microbar and must be multiplied by 10^{-5}. PressScale is stored with units of (nanobar / count) and must be multiplied by 10^{-8}. PressScale_2 is output with units of (pico-decibar/count^2) and must be multiplied by (10^{-12}). See Appendix 2 for details on the binary data format.

When using the data conversion software to extract ADP binary data files into ASCII format, the conversion from counts to decibar is done automatically by the software.

6.6.   Routine Maintenance

Under normal conditions, the ADP requires little maintenance for years of reliable performance. Normal wear does not change performance and the instrument never requires re-calibration for velocity data. This section discusses a number of routine maintenance procedures we suggest following.

Zinc anodes

The ADP housing includes sacrificial zinc anodes for corrosion protection. Under normal operating conditions, these anodes will last for several years. However, the lifetime of zinc anodes is highly variable depending upon the deployment environment. Anodes should be checked regularly - to check anode condition, scratch the anode with a screwdriver. If large pieces of the anode can be removed, the anode should be replaced. The anodes are a standard size that can be purchased through most marine supply stores. Please contact SonTek if you have trouble locating replacement anodes.

Cleaning the transducers

Biological growth on the transducers does not affect velocity measurements, but can decrease acoustic signal strength and reduce the effective profiling range of the ADP. Periodic cleaning of the ADP transducers may be needed to maintain optimal performance in areas of high biological activity.

High frequency ADP transducers (1.5 and 3.0 MHz) and encapsulated in an epoxy that is impervious to damage from barnacles or other types of growth. To remove growth, simply clean with a stiff (non-metallic) brush. The transducer epoxy is very durable and cannot be easily damage except by direct impact.

The 250 and 500-kHz ADP transducers are encapsulated in polyurethane (to increase efficiency at the lower acoustic frequency). The polyurethane is softer than the epoxy used with higher frequency transducers, and more susceptible to damage. Extended barnacle growth on the 250 and 500-kHz transducers can potentially cause serious transducer damage. Take care when removing growth to avoid damage to the transducer. Carefully clean 250 and 500-kHz transducers with a stiff (non-metallic) brush.

We recommend coating the transducers with anti-fouling paint for deployments in regions of high biological activity (see section 6.8).

Cables

The underwater cables used with the ADP are often the most vulnerable portion of the system. All standard SonTek cables use a durable polyurethane jacket that provides excellent long-term wear and abrasion resistance. However, any underwater cable is susceptible to damage and reasonable precautions should be taken. Inspect all ADP cables and connectors for damage on a regular basis, and replace if necessary.

O-rings

All ADP housings use a dual (redundant) o-ring seal wherever possible. All SonTek o-ring seals are designed for full ocean depth pressures, even if the housings and transducers have much lower pressure ratings. The o-rings will provide faultless performance as long as care is taken whenever the system is opened. Whenever the housing is opened, clean and inspect all o-rings and o-ring surfaces; replace o-rings when necessary. While the system is open, protect o-ring surfaces from scratches or other damage. Spare o-rings are included in the ADP tool kit.

Condensation in ADP Housings

Moisture in the air can potentially damage ADP electronics if it is allowed to condense inside the ADP housing. To prevent this, all underwater housing include an internal desiccant pack to absorb moisture. Whenever opening the ADP housing, take care to minimize the exposure of the desiccant to humid air. If you suspect the desiccant has been exposed sufficiently to saturate, replace the packet before closing the housing (spare desiccant is included in the ADP tool kit). When possible, purge the housing with a dry, inert gas (Nitrogen, Argon) before closing.

6.7. Trouble Shooting

This section provides some basic pointers for trouble shooting problems with the ADP, and should be useful in establishing the exact cause of most typical problems. If you have trouble finding the source of a problem with the ADP, please contact SonTek directly.

Cannot communicate with the ADP

If you are unable to establish communications with the ADP, the following list may help in identifying the problem.

- Power source - be sure that the power supply is providing between 12-24 V DC. When power is first connected to the ADP, it should automatically wake up and enter the last mode it was in (command mode, data acquisition mode, or deployment mode – see sections 3.1 and 3.2). Measure the input current when power is applied – it should typically be 50-200 mA. Try using an alternative power source if possible.

- Computer – be certain that the computer serial port is functioning correctly; ports on some laptop computers have been known to have problems. Try using another computer if possible.
- Communication parameters - be certain that the baud rate, communication serial port, and other operating parameters match ADP settings (see SECTION 3).
- Cable connections - be sure that all wiring to the ADP is securely connected and that each connector is properly wired.
- If the ADP software programs are unable to establish communications (ADPSA, COMPCAL, SONREC), try direct communications using a terminal emulator (SONTERM). When power is applied, see if the ADP will respond to a BREAK.
- Fuse - there is an input power fuse on the top corner of the analog board (see section 5.3). The fuse can be pulled directly from the socket on the board and tested for conductivity. Spare fuses are included with the ADP tool kit.

Compass/tilt sensor

If you suspect a problem with the ADP compass/tilt sensor, follow the procedure outlined in section 4.1 for a basic function test. Performing the test using both the output from the terminal emulator and the compass calibration software. If problems with heading data are apparent, perform a compass calibration and re-test compass function. A bad compass calibration can cause a major distortion to the heading data. Whenever testing compass operation, be sure the ADP is oriented properly based upon compass installation (up or down looking – see section 4.2).

Unreasonable velocity data

If the velocity data from the ADP does not appear reasonable, the following list may be helpful in establishing the source of the problem.

- Check the signal amplitude and signal to noise ratio (SNR) data. See the ADP Principles of Operation for a description of the expected behavior of these data. Be sure that the data have a sufficient SNR for reliable operation. Check that no large objects (structures, lines, fish, etc.) are interfering with the ADP acoustic beams.
- Check the standard deviation data. See the ADP Principles of Operation for a description of the expected behavior of these data. Check that the standard deviation values are reasonable based upon the values of averaging interval and cell size (see the ADP Principles of Operation to calculate the expected standard deviation). Large standard deviation values (with sufficient SNR levels) may be caused by motion of the deployment package. Look at the compass/tilt sensor data to see if the system orientation shows large changes.
- Look at the compass/tilt sensor data. In particular, look for large tilt values that may indicate that the deployment package is not laying flat (or is even upside down). Also observe how these values change with time to see if the deployment package is moving.
- Consider any possible influences of the deployment environment. Common problems include underwater structures, deployment lines and cables, and schools of fish attracted by underwater moorings. Also consider possible nearby sources of flow interference (bridges, piers, etc.) that might change the expected velocity signal. Areas of highly turbulent flow and large amounts of submerged bubbles can also affect velocity data.
- Look at the data from the temperature and pressure (if installed) sensors to see if the sensors are reporting reasonable values.

- Re-evaluate the deployment parameters (particularly cell size, number of cells, and all timing parameters) to see if these might have had some unforeseen effect on ADP performance.

Cannot retrieve data from internal recorder

There are several common causes of communication errors when retrieving data from the ADP internal recorder, as listed below.

- The software is being run from a DOS prompt within Windows rather that a dedicated DOS environment. Memory resident features of Windows interfere with serial port operation. All ADP software should be run from a dedicated DOS environment.
- The data extraction baud rate is too high for reliable operation. This can be a function of the length and quality of cables, the computer, and the operating environment (for external sources of noise). Run SONREC using a lower extraction rate (see the ADP Software Manual).
- Some computers have poor quality serial ports and are unable to retrieve large amounts of data at high baud rates. Run the data retrieval software using a lower extraction rate (see the ADP Software Manual). If problem persists, use another computer if possible.

If you are still unable to retrieve data from the internal recorder using SONREC, establish direct communications with the ADP and use the recorder commands to access data files directly (see section 3.9). Check that the file size and number of profiles recorded is reasonable based upon the deployment length and user setup parameters. Download the configuration and some portion of the data manually to verify that all data are present.

Missing data from autonomous deployment

The ADP internal recorder was designed for extremely high reliability, and we have not had a single recorder failure to date. The only data losses have occurred because of problems with the ADP power supply. If you have a deployment that appears to be missing some data, look at the date/time and battery voltage recorded with each profile. Check that these values are reasonable based upon the type of power supply used and the length of the deployment. If you cannot determine exactly what has occurred, place the data file (or a portion of it) on our FTP site and contact SonTek directly (see SECTION 89). We will look at the data as soon as possible.

6.8. Protection from Biological Fouling

The ADP has excellent resistance to biological fouling and can operate reliably even with biological growth on the transducers. Biological growth causes a loss in signal strength (reducing the signal to noise ratio (SNR)), but does not affect velocity measurements. The loss of signal strength will act to reduce the maximum profiling range of the ADP.

Both the ADP transducers and the underwater housings can be coated with commercial anti-fouling paints to prevent biological growth. If applied properly, the paint will have no effect on the instrument housing, although it can potentially decrease the lifetime of the sacrificial zinc anodes. Thick layers of anti-fouling paint on the transducers will cause a decrease is acoustic signal strength and will reduce the effective profiling range of the ADP. However, for most applications the loss of signal strength caused by anti-fouling paint does not have a significant effect on instrument performance (typical loss is 5-10% of maximum profiling range).

Within the United States, we recommend using an anti-fouling paint called Interlux Tri-Lux II on all areas except 250 and 500-kHz transducer (see below). This contains a biocide, a copper derivative, which allows its use on all metals, including aluminum. For information on Interlux paints, contact:

Courtaulds Coatings
2270 Morris Avenue
Union, NJ 07083 USA
Phone (908) 686-1300
Fax (908) 686-8545

Normal anti-fouling paints, which use cuprous oxide based biocides, cannot be applied on aluminum as they cause galvanic corrosion. Outside the United States, anti-fouling paints containing TBT can be applied on aluminum systems with a suitable primer. On plastic systems, any type of anti-fouling paint can be used.

IMPORTANT: For 250 and 500-kHz transducers, use only an anti-fouling paint approved for urethane transducers. These special types of paints are available from most marine supply stores. One suitable paint is MDR Transducer Anti-Fouling Paint available from West Marine (contact information is below).

West Marine
P.O. Box 50050
Watsonville, CA 95077-5050 USA
Phone (800) 538-0775 / (408) 728-4430
Fax (408) 728-4360

When painting metal housings, a suitable conversion layer must be applied to the metal for adhesion and to isolate the metal from the anti-fouling paint. If the metal has been powder coated (as the ADP transducers, head, and housing are), this acts as an excellent conversion layer. If no powder coat is present, or if the powder coat has been damaged, we suggest Interlux 360 Underwater Metal Primer. The primer should be applied to all exposed metal surfaces **except** sacrificial zinc anodes. The primer should not be applied to the transducers, the cable, or to areas where the powder coat is intact. Apply the anti-fouling paint to all surfaces of the instrument that require protection. Follow the instructions on the paint container with the following exceptions.

- Apply only **one** coat of anti-fouling paint to the transducers. Each layer of paint will cause some loss in signal strength and multiple layers can potentially affect system performance. Ensure that the paint has a smooth, even surface with no air bubbles.
- **IMPORTANT**: Do not paint the sacrificial zinc anode. Doing so will remove all corrosion protection.

If anti-fouling protection is desired for some portion of the cable, the paint can be applied directly to the polyurethane jacket without primer.

SECTION 7. Autonomous Deployment

7.1.   Selecting ADP Operating Parameters

The choice of ADP operating parameters depends upon the nature of the deployment and the goal of the study. While many applications would prefer the finest possible spatial and temporal resolution, this must be balanced with instrument performance, battery power limitations, and data storage requirements. Some guidelines for selecting the most important ADP operating parameters are given below. For more information about each parameter, see SECTION 3.

System parameters: output mode, output format, recorder, recorder mode
The settings of output mode (Auto/Polled) and output format (ASCII/Binary) are not important for autonomous deployment, as they affect only the data output over the serial port and not data stored to the internal recorder. The recorder setting (On/Off) only affects data collection initiated with the "Start" command; all autonomous deployments should be initiated with the "Deploy" command which will force the recorder "On". The recorder mode setting (Normal/Buffer) is typically "Normal" for autonomous deployments; the system stops recording data when the recorder is full. Buffer mode, where the oldest data are overwritten when the recorder is full, is typically selected when the recorder is acting as a data backup for real-time data installations.

Sound speed: temperature, salinity, and temperature mode
For most ADP deployments, temperature mode is set to "Measured" and the user-specified temperature has no effect on instrument operation. User input salinity should be as accurate as is practical; in regions with large variations, a mean value should be entered. A salinity error of 12 ppt results in a velocity error of 1%, so salinity variations typically have a minimal effect. If precise temperature and salinity records are available, ADP velocity data can be easily corrected for sound speed errors in post-processing (see ADP Principles of Operation).

Coordinate system
For most ADP deployments, the ENU (East-North-Up) coordinate system should be selected. This allows the instrument to perform a vector average of velocity data during each averaging interval. If ADP orientation changes, the mean profile reflects the true velocity and is not contaminated by instrument motion. Other coordinate system settings (BEAM or XYZ) are intended for experienced users in specialized applications.

Profile definition: blanking distance, cell size, and number of cells
For most ADP deployments, the blanking distance is left at the minimum (default) setting. Cell size is chosen based upon the desired resolution, profiling range, averaging interval, and accuracy. If the total water depth is near the maximum profiling range of the ADP, a larger cell size uses a longer pulse and will give a longer effective profiling range. See the ADP Principles of Operation for details on calculating the expected accuracy based upon the cell size and averaging interval.

The number of cells selected is based upon the cell size and the expected profiling range. SonTek recommends recording several cells beyond the expected end of the profile. This ensures that all meaningful velocity data are recorded and provides useful diagnostic data for post-processing. However, the number of cells should not be extended considerably beyond the expected profiling range, as this will increase data storage requirements and can potentially reduce the system pinging rate and increase the uncertainty in velocity data.

Timing parameters: averaging interval, profile interval, and burst sampling
As mentioned above, the choice of averaging interval is coupled with cell size and the desired accuracy. However, in many environments the required averaging time is not determined by the ADP, but by real variations in the flow. All of these factors should be taken into consideration when determining the averaging interval for a given deployment.

For most autonomous deployments, the combination of averaging interval and profile interval determines the instrument duty cycle and thus the total battery life. Burst sampling (collecting a number of profiles in rapid succession followed by a sleep period) allows the user to monitor both the short-term and long-term variations in flow, while maintaining a low overall duty cycle. Burst sampling increases the amount of data recorded and may encounter limitations on storage space. The increased data storage requirements and retrieval time required for burst sampling may have a significant impact on field operations. For details on storage requirements, see section 7.2. For details on data retrieval times, see the ADP Software Manual.

Pinging rate and ping interval
For most ADP applications, ping interval is left at the default value of 0.0 seconds, allowing the ADP to ping as rapidly as possible. Using other settings can reduce power consumption, but at the cost of reducing the number of samples, thereby increasing the uncertainty in velocity data. Section 7.2 gives an idea of the power savings that can be expected using a reduced pinging rate. For most applications, we recommend using the default setting of 0.0 seconds.

7.2.   Calculating Battery Life and Data Storage Requirements

Power consumption

ADP power consumption varies primarily with acoustic frequency, cell size, and pinging rate. It also varies slightly among systems of the same frequency using the same operating parameters. Other factors that influence power consumption are mode of operation (e.g.; bottom-track on or off), internal and external sensor use, and battery temperature.

The ADP ping rate can be adjusted using the ping interval parameter (see section 3.7). The default setting of 0.0 seconds causes the ADP to ping as rapidly as possible (20, 9, 14, 6, and 2.5 Hz for the 3000, 1500, 1000, 500, and 250-kHz systems, respectively). Other settings set the minimum time between pings; a setting of 0.5 seconds gives a ping rate of 2 Hz, while a setting of 1.0 second gives a ping rate of 1 Hz. Settings less than 0.5 seconds are not used by the ADP and will result in the maximum ping rate. Settings as high as 10.0 seconds are allowed (ping rate 0.1 Hz). However, we do not normally recommend settings higher than 1.0 second, as this can cause aliasing if the ADP is deployed in a wave environment.

For most applications, we recommend using the maximum ping rate (ping interval 0.0 seconds). The power savings achieved with a lower ping rate are offset by the loss of precision in velocity data caused by the reduced number of samples. Other ping interval settings are for special applications by experienced users. If you have any questions, please contact SonTek.

Typical power consumption values for all ADP frequencies (at two cell size settings and a number of ping rates) are shown in the following table. When using ping interval to control pinging rate, power consumption scales linearly with the ping rate.

ADP Power Consumption (W)

Frequency (kHz)	Cell Size (m)	Standard ADP	Parallel-Pinging ADP	
		Maximum Ping Rate	Maximum Ping Rate	1 Hz Ping Rate
3000	0.25	**2.5**	-	-
3000	0.5	**3.0**	-	-
1500	0.5	**2.0**	-	-
1500	1.0	**2.5**	-	-
1000	1.0	**2.5**	3.5	2.0
1000	2.0	**3.0**	4.5	2.5
500	2.0	**2.5**	5.5	2.5
500	4.0	**3.0**	7.5	3.0
250	2.0	**2.5**	5.5	2.5
250	4.0	**3.0**	7.5	3.0

Battery life

SonTek alkaline battery packs are wired for 18 V with a nominal capacity of 42 Ah; lithium packs output 21.6 V with a nominal capacity of 84 Ah (see Appendix 2 for battery back construction). When calculating battery life, we recommend using 80% of the nominal capacity to allow for temperature variations (nominal capacities are at 20°C) and a reasonable safety margin. Thus alkaline and lithium packs have working capacities of (0.8 * 18 * 42 = 600 Wh) and (0.8 * 21.6 V * 84 Ah = 1450 Wh), respectively.

Autonomous ADP systems hold three battery packs with a total capacity of 1800 and 4350 Wh for alkaline and lithium batteries, respectively. Battery life for continuous operation is simply the total capacity divided by the system power consumption. Thus a 1.5 MHz ADP with a 1.0 m cell, using the maximum ping rate for a power consumption of 2.5 W, can operate continuously for about 30 days on three alkaline battery packs.

For most applications, the ADP can use a reduced duty cycle to conserve battery power and extend deployment length (refer to section 1.3 to calculate the duty cycle.) When not actively collecting data, the ADP consumes less than 1 mW of power; battery life increases proportionally with the duty cycle. A 50% duty cycle will double the battery life; a 10% duty cycle increases battery life by a factor of 10.

With alkaline batteries, output voltage decays with use and can be an indicator of remaining battery life. Battery voltage as measured by the ADP (see section 3.10) will typically start at a level of about 17.4 V for new alkaline batteries. Alkaline battery packs typically stop working at a measured voltage of about 14 V; capacity is roughly linear within this range. Thus alkaline battery packs with a measured output voltage of 16 V can be estimated to have slightly more that 50% of the original capacity remaining. Note that these numbers are approximate only and will vary considerably, particularly with the temperature of the deployment.

When using lithium batteries, the voltage remains relatively constant throughout battery life and does not provide an indicator of remaining battery life.

Data storage

The amount of data per profile is a function of the number of acoustic beam (2, 3, or 4) and the number of depth cells recorded (1 to 100). The ADP profile header size is 82 bytes and the profile size is:

```
PROFILE_SIZE = 82 + (N_BEAMS * N_CELLS * 4) (basic configuration)

FILE_SIZE = (N_PROFILES * PROFILE SIZE) + 416
```

The profile size will also vary if the ADP includes CTD/Bottom Track/SONWAVE options. For more detail on data storage with optional features please refer to section 8.4.

The total file size is then the profile size multiplied by the number of profiles plus the file header (416 bytes). The ADP recorder is available in sizes ranging from 10 to 80 Mbytes and can accommodate a wide range of sampling strategies and deployment lengths.

The ADP recorder is divided into blocks of 64 Kbytes; only one data file can be written in each block, although one data file may occupy multiple blocks. Thus the recorder has a maximum number of files that can be stored based upon the recorder size (160 files for a recorder with 10 Mbytes capacity). If you record a large number of small data files (less than 64 Kbytes per file), the recorder will fill before reaching the rated maximum capacity.

7.3.   Starting an Autonomous Deployment

Autonomous deployments are started from the ADP direct command interface using a terminal or terminal emulator. The ADP software includes a DOS based terminal emulator called SONTERM (see the ADP Software Manual). See SECTION 3 regarding the direct command interface.

To start an autonomous deployment, establish direct communication with the ADP. There are four "Show" commands that display all operating parameters.

- "Show Conf"   - hardware configuration parameters
- "Show System"   - system operating parameters
- "Show Setup"   - data collection parameters
- "Show Deploy"   - autonomous deployment parameters

If you verify the settings of the parameters shown by the four commands above, you can be confident of a successful deployment. Refer to section 3.12 for sample outputs of the "Show" commands. Below is a list of recommended steps when starting an autonomous deployment. These include redundant checks to verify all aspects of ADP operation.

1. **IMPORTANT**: Always perform the deployment procedure with the ADP connected to and operating from the battery pack that will be used for deployment. Do not disconnect the battery pack after initiating the deployment (see section 3.2 for details).
2. Prior to deployment, perform a compass calibration (see section 4.4). If practical, this should be done with the system mounted in the deployment frame with batteries and other instrumentation installed.
3. Record all communication with the ADP for future reference. This can be done using the Alt+F option in SONTERM (see the ADP Software Manual).

4. Send a BREAK to wake the system up and establish communication.
5. Send the "Show Conf" command; check parameters to see they match desired/expected settings.
6. Send the "Show System" command; check parameters to see that they match desired settings. Of particular importance are the ADP date/time and the recorder mode setting. Modify parameters as needed.
7. Send the "Show Setup" command; check parameters to see that they match desired settings. Of particular importance are cell size, number of cells, averaging interval, profile interval, and ping interval. Modify parameters as needed.
8. Send the "Show Deploy" command; check parameters to see that they match desired settings. Of particular importance are deployment name, start date and time, and the timing parameters (averaging interval, profile interval, ping interval, and burst sampling parameters). Modify parameters as needed.
9. Send "Save Setup" command to save all entered parameters (this is redundant - done automatically by "Deploy" command).
10. Check compass operation by sending "Compass CONT". Rotate and tilt the ADP to verify performance (see section 4.1). Press any key to stop output.
11. Check recorder status using the "Dir" command. Make sure there is sufficient space for the data from this deployment; format the recorder if necessary.
12. Check overall system performance by sending the "Test" command.
13. Verify settings in all four "Show" commands one final time.
14. Send "Deploy" command to initiate the deployment. Watch for any error messages or for any unexpected response. If practical, leave the computer connected to the ADP until the first profile has been output.
15. **IMPORTANT**: Disconnect the cable from the computer prior to turning the computer off. Some computers will send the equivalent of a BREAK over the serial port when turned off, which can interrupt the deployment and cause the loss of data.
16. Disconnect the communication cable, install the dummy plug, and deploy the ADP.

SECTION 8. ADP Optional Features

8.1. ADP Wave Package: SONWAVE / SONWAVEPRO

The SONWAVE/SONWAVEPRO wave data collection packages allow the ADP to collect wave height data, including the wave-frequency spectra. To facilitate wave measurements and reduce demands on power and storage capacity of the ADP, SonTek implemented the following scheme for pressure data collection. Beginning with firmware version 7.1 (February, 2001), commands were added to process wave times-series data for pressure (P) and horizontal (UV) velocities. When wave data collection is enabled, the ADP samples the pressure sensor at a specified rate for a specified duration and stores raw pressure data in the recorder. You can choose how often the pressure series needs to be collected: one pressure record every n^{th} profiles (Figure 15).

When recording of pressure time series is enabled, the ADP records the mean and the standard deviation of pressure over the averaging interval and stores them with the header information.
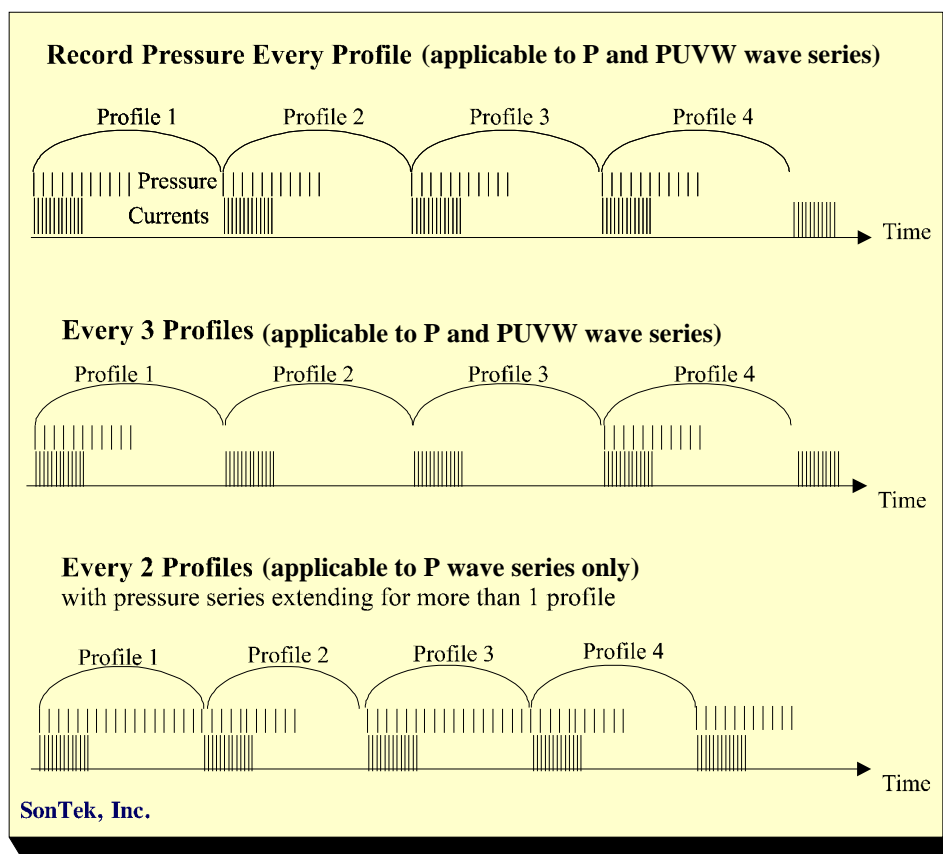

Figure 15: Examples of different sampling strategies for recording pressure time series using the SONWAVE/SONWAVEPRO package.

After uploading the data from the ADP to a PC, you can get a wave-frequency or directional spectrum, and/or extract the raw pressure time series, using the software provided as a part of the SONWAVE/SONWAVEPRO package. The following section describes the commands used for wave data collection with the ADP.

8.1.1. Setting up ADP to Collect Pressure Time Series

Wave setup commands that affect pressure time series data collection of the ADP. In this section, each command is shown (with any command line options) in *Italic*. Short versions of these commands, if they exist, are shown in parenthesis on the same line.

Summary of the ADP Wave Data Collection Commands

Command	Shortcut	Function
Help Wave	H wave	Help on wave data collection commands
Show Wave	S wave	Displays current setting of wave data collection
RecordWseries	RWS	Enables wave data collection and specifies how often pressure time series data is collected
WseriesRate	WSR	Sampling rate for wave (P or PUVW) time series collection; Hz
WseriesLength	WSL	Number of samples (128-4096) in wave series (P or PUVW). Note: Wave series length in seconds equals WSL/WSR.
WseriesType	WST	Selects the wave series type: P_SERIES or PUV_SERIES
OutPseriesMode	OPM	Pseries acquisition mode; AUTO or POLL

S wave

This command displays the currently active wave parameter settings.

RWS <d >

This command controls collection/recording of the pressure series data. Given without argument, RWS returns the current setting. When entered with a valid argument ($d>0$), the pressure data will be collected every d profiles (note that the time between successive pressure records will be $d\times$PRI, where PRI is profiling interval in s). If $d=0$ is specified, no pressure data is collected.

WSR <d>

This command specifies the sampling rate for the wave (P or PUVW) time series collection. When given without argument, WSR returns the current sampling rate [Hz] for collecting wave time series. When entered with a valid argument (1, 2, or 4 Hz), WSR sets the sampling rate.

WSL <d>

This command sets the length of the wave time series (in samples). When given without argument, WSL returns the current length of the wave time series. The length of the wave series in seconds equals WSL/WSR. When entered with a valid argument (128-4096 samples), WSL sets the time series length. Because the SONWAVE wave extraction software uses 128-second data segments, we recommend that WSL be a multiple of that number. For more accurate wave parameter estimation, we also recommend a minimum wave series length of 1024 seconds. However, you may choose smaller values if desired.

WST <P_SERIES / PUV_SERIES>

This command sets the wave series type. P_SERIES tells the system to collect pressure series data only. PUV_SERIES tells the system to collect pressure, U, V, and W data.

OPM <AUTO/POLL>

Pressure series acquisition mode: AUTO or POLL. A POLL mode enables a user to request wave data exactly when required.

8.1.2. SONWAVE/SONWAVEPRO *Output ASCII Data Format*

This section describes the format of the ADP ASCII SONWAVE data coming over a serial port when either acquiring data in real-time using a terminal emulator or reading the data from the recorder using recorder commands. This description is complimentary to Section 3.14.2. The SonWave data comes immediately after the corresponding profile data (see Section 3.14.2).

```
Wave header    32   DEFAULT      C23           1 1997 10 15 10 49 0 1 6 1 1 150
Pressure series 2000     2000     2000     2000     2000     2000
```

The header format is as follows:

- Data Type (internal)
  Number of bytes (internal)
  System serial number (c23)
  ProfileNumber
  6 values for profile time (year, month, day, hour, minute, second)
  SensorType: 0-Strain gage, 1-Paros, 2-Druck
  WseriesRate in Hz (1, 2, or 4)
  WseriesLength in samples (128-4096)
  Wave Spectra Recorded (0-No, 1-yes)
  Water Depth (cm)
  10 wave spectral amplitude bands (cm)
  Wave significant height Hmo (cm) and peak period (s)

A wave Header is followed by a pressure time series (P_SERIES) consisting of WseriesLength 3-byte unsigned integers. Each integer will contain:
- For Strain-gauge, raw A/D converter counts
- For Serial Paros, pressure in 0.001 dbars
- For Druck, frequency in 0.001 Hz

If WseriesType (WST) is set to PUV_SERIES, the above-mentioned P_SERIES data is followed by U, V, and W data consisting of WseriesLength 2-byte unsigned integers that contain:
- U data in mm/s
- V data in mm/s
- W data in mm/s

8.1.3. Wave Data Conversion: GADPPRES, GADPPUV, and GADPWAVE

In order to extract wave information the following programs are provided:

- GADPPRES   Extracts raw pressure time series.
- GADPPUV   Extracts raw PUVW time series data.
- GADPWAVE Computes wave frequency spectra using recorded pressure time series.

If the name of any of these programs is entered by itself, the program will display information on its usage and a description of the parameters that can be specified on the command line.

Pressure (or PUVW) Time Series Conversion: GADPPRES (or GADPPUV)
This program extracts the pressure time series (or PUVW) data recorded in the ADP file and outputs data into an ASCII file in a tabular form. Each time-series can occupy several consecutive lines with each line containing the profile number corresponding to the profile when the time-series was started, followed by eight consecutive pressure values (in dbars) for GADPPRES. If GADPPUV is run, three additional lines are extracted that contain the U, V, and W data respectively (in mm/s). The command syntax is as follows.

```
GADPPRES <ADP file> <-Ooutput file> <-Nfirst_series:last_series> or
GADPPUV  <ADP file> <-Ooutput file> <-Nfirst_series:last_series>
```
Where

- <ADP file > specifies name of the ADP raw data file without an extension (.adp is assumed). This argument is mandatory.
- <-Ooutput file> specifies name of the output data file without an extension (.pts is appended for GADPPRES; .puv is appended for GADPPUV). This argument is optional, when omitted the name of the input file is used.
- <-Nfirst_series:last_series> allows to extract a portion of the data: first series and last series specify the first and the last series to extract. If no series number is specified the program extracts all profiles in the file.

The following example extracts pressure records from 21 to 100 from the file test001.adp, and outputs data to file test001.pts (or test001.puv if GADPPUV is used).

```
GADPPRES test001 –N21:100
```

Wave Height Spectra Extraction: GADPWAVE
This program extracts the pressure time series recorded in the ADP file, computes wave frequency spectra, and stores them in an ASCII file in a tabular form. Note that GADPWAVE only computes wave height spectra (non-directional); to compute wave directional spectra, use the *ViewADPPro* postprocessing software (Windows-based). Each wave record line contains the profile number (at the start of the time series), followed by wave amplitude values (cm) for 10 consecutive period bands, significant wave height (cm), and wave peak period (s). Typical command formats are as follows.

```
GADPWAVE <ADP file> <-Dwater_depth> <-Ooutput file>
GADPWAVE <ADP file> <-Dwater_depth> <-Nfirst_profile:last_profile>
GADPWAVE <ADP file> <-Dwater_depth> <-Pfilename>
```

- <ADP file > specifies name of the ADP raw data file without an extension (.ADP is assumed). This argument is mandatory.
- <-Ooutput file> specifies name of the output data file without an extension (.WAV is appended). This argument is optional, when omitted the name of the input file is used.
- <-Nfirst_series:last_series> allows to extract a portion of the data: first series and last series specify the first and the last series to extract. If no series number is specified the program extracts all profiles in the file.
- <-Dwaterdepth> Specifies the water depth at the deployment site. This parameter is necessary for choosing the appropriate dispersion relation in wave spectra computations. If not given, ADP depth (from mean pressure) is used. Water depth < 0 is interpreted as the height of the

> ADP above the bottom (height of the ADP within the mooring structure), and it is used together with the mean pressure to determine the true water depth. Last option is most commonly used when the exact depth of the site is unknown.

- <-Pfilename> Druck or Frequency Paros calibration file. This is needed to convert the raw frequency data to actual pressure. The program assumes the filename extension is .DRK

The following example extracts pressure records from 21 to 100 from the file test001.adp, and outputs data to file test001.wav using a wave dispersion corresponding to water depth of 20 m; uses calibration file 11845261 to convert raw frequency data to actual pressure from a Druck/Paros pressure sensor.

```
GADPWAVE test001 -D20 N21-100 -P11845261
```

Wave Frequency Spectra Calculations (SonWave/SonWavePro)

The wave-frequency spectra are estimated using standard methods appropriate to simple linear theory. It includes: segmentation of the data into 256-sample segments with at least 128-samples overlap between consecutive segments; application of Hanning window to each segment with constant energy correction; and correction for sensor/water depth using a generalized first order dispersion relationship for surface waves.

The wave spectral estimates are presented as an array of coefficients, each giving the mean wave amplitude (proportional to square root of the energy) within a period band. Ten bands are used, which correspond to wave periods in the range:

Band #	Period range [s]
1	2 - 4
2	4 - 6
3	6 - 8
4	8 - 10
5	10 - 12
6	12 - 14
7	14 - 16
8	16 - 18
9	18 - 20
10	20 or longer

For each band the software computes the mean wave amplitude *A*, which is an integral of wave contributions within the period range in the band. If A_i is the amplitude for band i, the total wave energy is simply given by:

$$Total\ Energy\ (\sigma_A^2) = 0.5 \sum_{i=1}^{10} A_i^2$$

SONWAVE/SONWAVEPRO outputs the band amplitudes in cm for consistency with velocity data, which are reported in cm/s. A generally accepted estimate of the significant wave height can be easily obtained from the amplitudes using:

$$H_{mo} = 4\sqrt{Total\ \ energy}$$

For a complete description of directional wave computations, refer to the SonWavePro Application Note (SonWavePro.pdf) included in the *ViewADPPro* software directory.

8.1.4. Considerations when collecting pressure data

When wave data collection is enabled, the ADP will collect raw pressure samples spectral data at a specified interval. This has the following consequences:

Data storage
Since recording the pressure time series data requires additional memory the maximum number of profiles that can be stored in the ADP recorder is therefore reduced. To calculate recorder capacity with SonWave enabled refer to Section 8.5.

Power consumption.
With RecordWseries disabled, the ADP consumes power only during the averaging interval (power consumption during sleep is negligible- 1mW). When record pressure series is enabled, the ADP typically consumes the same amount of power during an averaging interval as when this feature is disabled. However, if the pressure series extends beyond the averaging interval the ADP will consume approximately 1 W, instead of 1 mW. This must be taken into account when calculating power requirements for a deployment.

Profiling interval
The duration of the pressure time series Tp must be at least 15 s less than the time between successive time series PRI. Also, the time between successive pressure records must differ by at least 15 s from can the duration of the profiling interval. For example, if PRI=300 s, RWS=1 (record pressure every profile), the maximum time duration of the wave series WSL must be less than 285 s. If PRI=300 and RWS=2 (record pressure every other profile), then 315<WSL<585 or WSL<285.

8.2.   ADP Bottom Track

In order to perform current surveys covering large areas vessel-mounted ADPs are often employed. However an ADP profiling from the moving vessel or platform measures relative current velocities that are comprised of the water velocity plus the motion of the vessel or platform. Thus, it is important to independently measure the platform velocity so that it can be subtracted from the raw velocity measurements to yield the residual absolute currents relative to the fixed Earth. Understandably, it is desirable to perform these calculations in real-time.

SonTek now offers a Bottom Track option for ADPs that allows a user to get real-time vessel-speed over ground simultaneously with the current measurements without any external additional hardware. While bottom tracking, the ADP measures the Doppler shift of reflected acoustic energy (from the bottom of a river, harbor, etc.) to infer the vessel speed. In contrast, when an ADP is current profiling, it is measuring acoustic reflections from suspended material in the water column to determine the velocity of the water with respect to the ADP.

In bottom tracking mode the ADP determines bottom velocity once every second. At the end of the averaging interval all these estimates are averaged for each beam stored together with the rest of the profile data.

8.2.1. Setting up ADP to Bottom Track

In this section, each command is shown (with any command line options) in *Italic*. Short versions of these commands, if they exist, are shown in parenthesis on the same line.

Summary of the ADP Bottom Track Commands

Command	Shortcut	Function
BottomTrack	BT	Enables & disables Bottom Tracking mode, with or without shallow water ping data.

BT <YES/NO/SW_PING>
This command enables & disables the Bottom Tracking mode. When this command is given without argument, it returns the current setting. When entered with an input argument YES or NO the Bottom Tracking will be enabled or disabled. Setting the argument to SW_PING tells the system to enable Bottom Tracking and to also collect Shallow Water ping data.

8.2.2. Bottom Track Output ASCII Data Format

This section describes the format of the ADP ASCII bottom track data coming over a serial port when either acquiring data in real-time using a terminal emulator of reading the data stored in the recorder using recorder commands. This description is complimentary to the SECTION 3.14.2. The bottom track data is stored in the line immediately preceding the profile data (see p. 28).

```
(BT=YES or SW_PING)  100    221    220    220    0     115  116   140 0
(BT=SW_PING)         500    771    350    100    1650 234  150   500
(BT=SW_PING)         0      0      0      0      53   14   29    0   0   1   1   0
```

The data format is as follows:

- Line 1 (when BT=YES or SW_PING) – Bottom track status (% good pings, indicating quality of bottom tracking); vertical range to the bottom (in mm) for each beam, bottom velocity (mm/s) for each beam.
- Line 2 (only when BT=SW_PING) – Shallow-Water (SW) ping pulse lag (mm); ambiguity velocity corresponding to the pulse lag (velocity range) in mm/s; beginning position and length (two values) of the SW cell (mm); remaining fields are spare diagnostic fields for SonTek's in-house use.
- Line 3 (only when BT=SW_PING) – Range to the bottom for each beam (four values in mm); velocity from the SW pulse for each beam (four values in mm/s); correlation from the SW pulse for each beam (four values in %).

8.2.3. Bottom Track Data Conversion: GADPBT

To extract bottom track information from the ADP data file, the following program is provided:

- GADPBT   Extracts bottom track data from the ADP data file .

GADPBT extracts the bottom track data recorded in the ADP file and outputs the data into an ASCII file in a tabular form. Each record contains bottom track information corresponding to a consecutive current profile. If the name of the program is entered by itself, the program will display information on its usage and a description of the parameters that can be specified on the command line. The command syntax is as follows.

```
GADPBT <ADP file>
GADPBT <ADP file> <output file>
GADPBT <ADP file> <output file> <-Nfirst profile:last profile> <-Mmagdecl>
GADPBT <ADP file> <output file> <-Mmagdecl> <-Ccoord system>
```

Where

- <ADP file > specifies name of the ADP raw data file without an extension (.ADP is assumed). This argument is mandatory.
- <-Ooutput file> specifies name of the output data file without an extension (.BT is appended). This argument is optional, when omitted the name of the input file is used.
- <-Nfirst_series:last_series> allows to extract a portion of the data: first series and last series specify the first and the last series to extract. If no series number is specified the program extracts all profiles in the file.
- <-Mddd.d> Magnetic declination in degrees. Default is *MagDecl* stored within the ADP data file. (Note: only the real-time program allows the inclusion of magnetic declination).
- <-Ccoord system> Change out put coordinates to XYZ or ENU. Default is to output data in the coordinates they were collected.

Example:

```
GADPBT test1 –O\data\test1 –M11.3 –N21:100 –CENU
```

extracts bottom track data for profiles 21 to 100 from the file test1.adp, and outputs data to file \data\test1.bt in ENU coordinates and uses 11.3° magnetic declination.

The extracted bottom track data are stored in a tabular format. The output file has a total of 9 columns, and 1 row for each profile is recorded. The table below describes the data.

ADP Bottom Track Output Profile Data

Column	Contents
1	Profile number
2	Bottom track status (percentage of 'good' bottom track pings during profile average)
3-5	Vertical range to the bottom (depth) [in meters] as detected by each of the 3 beams
6-8	Velocity of the bottom with respect to the ADP (in either Beam, XYZ or ENU coordinates) in cm/s

Notes:

　　Depth:　　Differences in range indicate either a non-flat bottom or that the ADP is tilted.
　　Velocity: Note: this is velocity of the *bottom* relative to ADP therefore it will normally be in the opposite direction from the actual velocity of the boat.

8.2.4. Considerations When Operating In Bottom Tracking Mode

Data storage
To store the bottom track data requires additional 4*NUMBEROFBEAMS+2 bytes to each profile, which results in a slight reduction in the maximum number of profiles that can be stored in the ADP recorder. To calculate recorder capacity with Bottom Track enabled see Section 8.5.

Power consumption.
With Bottom Tracking enabled the ADP consumes almost the same amount of power as without bottom track. Therefore, the same power consumption algorithms can be used.

Profiling interval
Since ADP tracks bottom once every second, to achieve stable performance it is advisable to have minimal averaging interval no smaller than 3 s.

8.2.5. Using GPS while bottom tracking with an ADP

The ADP is capable of recording GPS data while simultaneously bottom tracking. This not only provides a check between the two navigational methods, but it allows use of the GPS when the bottom is out of range. You then have all the advantages of both methods and the ADP software easily works with both data sets.

8.3. High-Resolution Ping Control (for Waves and SW Pings)

When using the ADP to collect wave data or shallow-water ping data, additional commands are available that relate to the coherent pulse parameters. These commands are described in this section and shown in the following table.

Special Parmeters for Collecting Wave Data and Shallow-Water Ping Data

CBD value	CohBlankDistance – Sets desired coherent-pulse blanking distance (m)
CCS value	CohCellSize – Sets desired coherent-pulse cell size (m)
CPG value	CohPulseLag – Sets desired coherent-pulse lag (m)
CPL value	CohPulseLength – Sets desired coherent-pulse length (m)
MCL value	MinimumCorrelationLevel – Sets minimum acceptable correlation value (%)
SCP	ShowCohPulse – Shows the above-mentioned coherent-pulse settings

CohBlankDistance <d.dd> and CohCellSize <d.dd>   (short commands "CBD" and "CCS")

Because of the higher spatial resolution required for wave data and shallow-water ping data, the ADP allows the use of smaller cell sizes and blanking distances.

CohPulseLag <d.dd> (short command "CPG")

CPG sets the lag between the ambiguity resolution pulses (coarse velocity measurements). This parameter will ultimately determine the maximum velocity range of the measurements. The ADP transmits an ambiguity resolution pulse before each profile and collects one velocity measurement in a single cell.

CohPulseLength *<d.dd>* (short command "CPL")

Sets the length of the coherent pulse. This command is normally <u>not</u> set in a standard ADP, where CS=PL. However, this parameter can be manually set for specialized applications such as wave data collection and shallow-water ping data.

MinimumCorrelationLevel <dd %> (short command "MCL")

MCL sets the minimum acceptable correlation value. During operation, the ADP transmits a series of pings. The results are averaged into an accumulator and stored at the end of the averaging interval. MCL lets you set the correlations level, below which the raw samples are not included in the average. A lower MCL means more data will be accepted, a higher MCL means more data will be rejected. When given without an input argument, MCL returns the current setting. Caution: Turbulent flows can cause low correlation values, which are due to the natural variability of the flow and may be acceptable for data collection.

ShowCohPulse   (short command "SCP")

This command displays the values of the parameters CPG, CPL, CCS, CBD, and MCL in addition to the regular ADP setup (see Section 3.7). It will also display the maximum vertical and horizontal velocities corresponding to the specified pulse lag.

8.4.   Optional Sensors: CTD, Resonance Pressure Sensors, External Analog

The ADP can include a number of externally mounted, integrated sensors (the sensors connected to the ADP using special interface cables). Two common sensors (the SeaBird MicroCat CTD and the Paroscientific pressure sensor) are integrated using an RS232 serial interface. The Druck resonance pressure sensor is integrated using a separate board. Other sensors (OBS, transmiss-ometer, conductivity, etc.) are integrated using analog output voltages. Depending on the type of sensor, it may receive input power from the ADP or it may use a separate power supply. For details on available sensors and configurations, contact SonTek directly.

8.4.1. SeaBird MicroCat CTD

The SeaBird MicroCat CTD with RS232 serial interface provides high quality conductivity, temperature, salinity, and pressure (optional) data. When integrated with the ADP, the MicroCat is sampled at the beginning of each averaging interval. Data are integrated in a CTD data structure within each ADP profile.

CTD Commands
Described below are commands necessary to setup the ADP for acquiring the CTD data. In normal operation all commands to the optional external CTD sensor are sent automatically and no direct commands need to be sent. The commands in this section are provided to assist in diagnosing problems and to give greater flexibility in ADP operations.

CTD Commands

Command	Shortcut	Function	
Help CTD	H/? CTD	External CTD sensor commands	
CTD	(none)	Display most recent CTD reading	
CTD CONT	(none)	Display continuous CTD readings	
CTD Talk	(none)	Direct serial communication with CTD	

H CTD
Displays help on external CTD sensor commands.

CTD
Display most recent temperature (°C), conductivity (Siemens per meter), pressure (decibar), and salinity (ppt) data from the external CTD sensor. Data are output in a self-explanatory, ASCII text format.

CTD CONT
Display most recent temperature (°C), conductivity (Siemens per meter), pressure (decibar), and salinity (ppt) data from the external CTD sensor. Data are output in a self-explanatory, ASCII text format. Press any key to stop data output and return to command mode.

CTD Talk
Establish direct serial communication with the external CTD. A manual for the CTD sensor is included; refer to this manual for more details on direct commands to the CTD. See section 8.2 for more details about the external CTD sensor. To return to command mode, type "+++" or send a BREAK to the ADP.

8.4.2. CTD Output ASCII Data Format

This section describes the format of the ADP ASCII CTD data coming over a serial port when either acquiring data in real-time using a terminal emulator of reading the data stored in the recorder using recorder commands. This description is complimentary to the SECTION 3.14.2, p 28. The CTD sensor data (if present) are given in a single line following the profile header data.

```
87514    468151        0    351354
```

The data format is as follows:

- CTD Temperature (units 0.0001 °C)
- CTD Conductivity (units of 0.00001 Siemens per meter)
- CTD Pressure (units of 0.001 decibar) (note the CTD may not include a pressure sensor)
- CTD Salinity (units of 0.0001 ppt)

8.4.3. Resonance Pressure Sensor

Paroscientific
Paroscientific pressure sensors are the standard for long-term tidal measurements because of their accuracy and excellent stability. A Paroscientific sensor of any range can be integrated with the ADP using a RS232 interface. Pressure data are sampled once per second during the averaging interval; mean and standard deviation of pressure are recorded. Paroscientific pressure data are integrated within the ADP profile header.

Druck
Druck resonance pressure sensors can provide an attractive alternative to rather expensive and bulky Paroscientific sensor. Although Druck sensors do not have a long history their accuracy and precision is well beyond that of the strain gage. In addition, due to a fruitful collaboration with Druck engineers, we now offer a resonance pressure sensor which is integrated into the ADP head. No external hardware and wiring required!

8.4.4. External analog sensors

Depending on system configuration, the ADP has up to 2 available analog input channels (0-4 V DC) for integrating a variety of sensors with analog output voltages. Common applications include OBS or transmissometer data for suspended sediment studies. Data are sampled once per second during the averaging interval; mean and standard deviation are recorded with each profile. For information on available sensors, contact SonTek directly.

8.5. ADP Recorder Capacity With Optional Features

This section describes how to calculate the ADP recorder capacity taking into account the data from the ADP optional features.

When SonWave is enabled,

the P_SERIES wave type of it extra PressureHeaderSize+WSL*3 bytes to each Nth profile; and
the PUV_SERIES wave type adds PressureHeaderSize+WSL*9 bytes to each Nth profile.

Therefore, the profile size needs to be adjusted accordingly.

When the Bottom Track is enabled, 18 extra bytes are added to each profile. When a CTD is installed, 16 extra bytes are added to each profile.

The equation for computing the data storage requirements needs to be modified as follows:

```
PROFILE_SIZE        = 82 + (N_BEAMS * N_CELLS * 4) +
                      16 (if CTD data is present) +
                      18 (if Bottom Track is enabled)

WAVESERIES_SIZE   = 82 + (3*WSL) (when WST is P_SERIES)
WAVESERIES_SIZE   = 82 + (9*WSL) (when WST is PUV_SERIES)
```

Where WSL is Wave Series Length (in samples).

The total file size then the profile size multiplied by the number of profiles plus the file header (416 bytes) plus the pressure series length multiplied by the relative fraction of pressure records expressed as the ratio of the total number of profiles / RecordWseries parameter.

```
FILE_SIZE         = 416 + (N_PROFILES * PROFILE SIZE) +
                    NPROFILES/RWS*WAVESERIES_SIZE (if RWS >0)
```

Where RWS is Record Wave Series parameter, determining how often the wave time series are recorded.

SECTION 9.   Additional Support

Any additional questions can be directed to SonTek by phone, FAX, or e-mail. Regular business hours are 8:00 am to 5:00 p.m., Pacific Standard Time, Monday through Friday.

Phone	(858) 546-8327
FAX	(858) 546-8150
E-mail	inquiry@sontek.com
World Wide Web	http://www.sontek.com
FTP	ftp://ftp.sontek.com/pub

See our web page for information concerning new products and software / firmware upgrades. SonTek also maintains an FTP site for software upgrades and data exchanges. You can either access the FTP site through our Web page or by an anonymous login to our FTP site at *ftp.sontek.com*, use your email address as a password, and use the path */pub*.

The FTP site includes a directory called "incoming" with external write privileges to accept incoming files. Note there are no external read privileges for this directory, so you will not be able to see the file after sending it to this directory. After sending the file, notify us by phone, fax, or e-mail and we will look at the data file as soon as possible.

There are a number of other directories on the FTP site providing software upgrades, demonstration software, and a variety of other information. In each directory is a file called "README" that provides information on what information is available and where to find it.

APPENDIX A. ADP Binary Data File Format

The file format described in this appendix is valid for ADP CPU firmware versions 3.0 and higher. The data conversion software (and source code) provided with the ADP will interpret all data files, for CPU firmware versions before and after 3.0. For more information about changes in the ADP data file format, contact SonTek directly.

A1. Overview

The basic structure of an ADP binary file with N profiles is shown below. The size of each profile is a function of the number of acoustic beams (NB can be 2, 3, or 4), the number of cells recorded (NC can be 1 to 100), and whether the file includes CTD and/or GPS data.

```
File Header 416 bytes
Profile 1 (NB*NC*4 + 82  + 16 (if CTD present) + 40 (if GPS present) (if
          Btrack is enabled) + PSL*3+80 (if SonWave is enabled)) bytes
Profile 2 (NB*NC*4 + 82  + 16 (if CTD present) + 40 (if GPS present) (if
          Btrack is enabled) + PSL*3+80 (if SonWave is enabled)) bytes
...
Profile N (NB*NC*4 + 82  + 16 (if CTD present) + 40 (if GPS present) (if
          Btrack is enabled) + PSL*3+80 (if SonWave is enabled)) bytes
```

The ADP file header consists of three binary structures in the following order.

```
ADP Sensor Configuration 96 bytes
ADP Operation Configuration 64 bytes
ADP User Setup Parameters 256 bytes
```

An ADP profile consists of three to five binary structures, depending upon whether CTD and/or GPS data are present.

```
Profile Header              80 bytes
CTD Data                    16 bytes (if present)
GPS Data                    40 bytes (if present)
Bottom Track Data           18 bytes (if enabled)
Profile Data                (NB*NC*4) bytes
SonWave Data                PSL*3+80 bytes (if enabled)
Profile CheckSum            2 bytes
```

Each of the structures mentioned above are described in detail (using their C language definitions) in the remainder of this appendix.

A2. File Header Structures

Each ADP file header structure is described below using the C language definition. The first structure, "ADP Date and Time Structure," is referenced by other structures.

ADP date and time structure (8 bytes)

```
typedef struct {
    int  year;
    char day,
         month,
         minute,
         hour,
         sec100,
         second;
} DateTimeType;
```

ADP sensor configuration structure (96 bytes)

```
typedef struct {
  char      ConfigType;              /* Type      0x10          */
  char      ConfigVer;               /* Version   0x02          */
  int       Nbytes;                  /* Bytes in configuration  */
  DateTimeType   ConfigTime;         /* Date created or modified */
  unsigned char   SoftwareVerNum;    /* Ver number of CPU firmware*/
  unsigned char   DspSoftwareVerNum;/* Ver number of DSP firmware*/
  char            BoardRev;          /* Electronics board revision*/
  char      SerialNumber[10];
  char      AdpType;                 /* 0-3; 1-1.5; 2-750; 3-500; */
                                     /* 4-250;                  */
  char      Nbeams;                  /* 2 or 3 or 4             */
  char      BeamGeometry;            /* 0- 2 Beams; 1- 3 Beams  */
                                     /* 2- 4 Beams, 1 Vertical  */
                                     /* 3- 4 Beams, Janus       */
  int       SlantAngle;              /* in 0.1 deg              */
  char      SensorOrientation;       /* 0-down; 1-up; 2-side    */
  char      CompassInstalled;        /* 0-No;   1-Yes           */
  char      RecorderInstalled;       /* 0-No;   1-Yes           */
  char      TempInstalled;           /* 0-No;   1-Yes           */
  char      PressInstalled;          /* 0-No;   1-Yes           */
  char      Spare1[1];               /* set to all 0s           */
  int       XformMat[16];            /* From Beam to XYZ veloc. */
  int       CompassOffset;           /* Degress to East of North */
  long      PressScale;              /* Nanobar per count       */
  long      PressOffset;             /* Microbar                */
  char      PowerSaveMove;           /* if 1 ADP turns off after */
                                     /* 5 min idle in command mode*/
  char      ExtSensorInstalled;      /* 0-No;   1-Yes           */
  char      ParosSensorInstalled;    /* 0-No;   1-Yes           */
  char      CtdSensorInstalled;      /* 0-No;   1-Yes           */
  unsigned int PressScale_2;         /* pico dbar per count^2   */
  char      Spare2[12];              /* set to all 0s           */
} AdpSensorConfigType;
```

ADP operation configuration structure (64 bytes)

```
typedef struct {
   unsigned char Bpar[64];
} AdpOperationConfigType;
```

User setup parameters structure (256 bytes)

```
typedef struct {
  unsigned   char      ConfigType; /* Type      0x12          */
  unsigned   char      ConfigVer;  /* Version   0x01          */
  unsigned   int       Nbytes;     /* Bytes in configuration  */
  DateTimeType         ConfigTime; /* Date created or modified */
  int          Temp;               /* 0.1 deg C               */
  int          Sal;                /* 0.1 ppt                 */
  int          Cw;                 /* 0.1 m/s                 */
  unsigned int Ncells;             /* # of depth cells in profile */
  unsigned int CellSize;           /* in cm                   */
  unsigned int BlankDistance;      /* in cm                   */
  long         SensorDepth;        /* in cm        (PC ver only) */
  char         TempMode;           /* 0- User value  1- Measured */

  unsigned int AvgInterval;        /* in s                    */
  unsigned int ProfileInterval;    /* in s                    */
```

```
    unsigned int   PingInterval;    /* in 0.1 s                    */
    unsigned int   BurstMode;       /* 0-Disabled; 1-enabled   */
    unsigned int   BurstInterval;   /* in s                        */
    unsigned int   ProfilesPerBurst;

    char           CoordSystem;     /* 0-Beam;     1-XYZ; 2-ENU    */
    char           OutMode;         /* 0-Auto;     1-Polled        */
    char           OutFormat;       /* 0-Binary;   1-Ascii         */
    char           RecorderEnabled; /* 0-DISABLED; 1-ENABLED       */
    char           RecorderMode;    /* 0-NORMAL MODE;1-BUFFER MODE*/

    char           DeploymentMode;    /* 0-Disabled; 1-enabled     */
    char           DeploymentName[9]; /* Dir name in recorder      */
    DateTimeType   BeginDeploymentDateTime;
    char           CommentLine1[60];
    char           CommentLine2[60];
    char           CommentLine3[60];

    char           AutoSleep;
    char           Spare[11];       /* set to all 0s               */
  } AdpUserSetupType;
```

A3. Profile Header/CTD/GPS/Bottom Track,/SonWave/Profile Data Structures

Each structure used to record the ADP profile data is given below. Note that the profile header structure refers to the "ADP Date and Time Structure" defined in A1.2.

<u>ADP profile header structure (80 bytes)</u>

```
  typedef struct
  {
    unsigned char  SyncChar;      /* 0xA5                              */
    unsigned char  DataType;      /* 0x10                              */
    unsigned int   Nbytes;        /* In profile header            */
    char           SerialNumber[10];
    unsigned long  ProfileNumber; /* From start of data collection*/
    DateTimeType   ProfileTime;   /* At start of avg interval      */

    char           Nbeams;             /* 2/3/4                        */
    char           SensorOrientation;/* 0-down; 1-up; 2-side      */
    char           TempMode;           /* 0-User value  1- Measured*/
    char           CoordSystem;        /* 0-Beam; 1-XYZ; 2-ENU      */
    unsigned int   Ncells;        /* # of depth cells in profile*/
    unsigned int   CellSize;      /* in cm                        */
    unsigned int   BlankDistance; /* in cm                        */
    unsigned int   AvgInterval;   /* in s                         */

    unsigned int   Npings;             /* Averaged in profile      */
    int            MeanHeading;        /* in 0.1  deg              */
    int            MeanPitch;          /* in 0.1  deg              */
    int            MeanRoll;           /* in 0.1  deg              */
    int            MeanTemp;           /* in 0.01 deg              */
    unsigned int   MeanPress;          /* in counts (0-65535)      */
    unsigned char  StdHeading;         /* in 0.1  deg              */
    unsigned char  StdPitch;           /* in 0.1  deg              */
    unsigned char  StdRoll;            /* in 0.1  deg              */
    unsigned char  StdTemp;            /* in 0.1  deg              */
    unsigned int   StdPress;           /* in counts                */
    unsigned int   SoundSpeed;         /* in 0.1  m/s              */
    unsigned char  Spare[2];           /* Reserved, set to 0       */
    unsigned char  Status[20];         /* TroubleShooting data     */
```

```
                    /* The 16th element in this array, Status[15],*/
                    /* is battery voltage in units of 0.2 V        */
                    /* Thus a value of 98 gives 19.6 V             */
    } ProfileHdrType;
```

CTD data structure (16 bytes)

```
    typedef struct {
      long          Temperature;   /* 0.0001  degrees C     */
      long          Conductivity;  /* 0.00001 Siemens per m */
      long          Pressure;      /* 0.001   decibar       */
      long          Salinity;      /* 0.0001  ppt           */
    } CtdType;
```

GPS data structure (40 bytes)

```
    typedef struct{
      long   StartUtc;   /* Profile start time, UTC seconds */
      double StartLat;   /* Position at start of profile    */
      double StartLon;   /* Decimal degrees                 */
      long   EndUtc;     /* Profile end time, UTC seconds   */
      double EndLat;     /* Position at end of profile      */
      double EndLon;     /* Decimal degrees                 */
    } ProfileGpsType;
```

Bottom track data structure (18 bytes)

```
    typedef struct{
      int Status;                            /* % good btrack pings in average */
      unsigned int Range[MAX_BEAMS];     /* in cm                        */
      int Vel[MAX_BEAMS];                /* in mm/s                      */
    }BtrackType;
```

Profile data structure (4*N_Beam*N_Cells bytes)

```
    typedef struct
    {
      int             Vel[N_BEAMS][N_CELLS];    /* in 1 mm/s */
      unsigned char VelStd[N_BEAMS][N_CELLS];   /* in 1 mm/s */
      unsigned char   Amp[N_BEAMS][N_CELLS];    /* in counts */
    } ProfileType;
```

SonWave header structure (80 bytes)

A wave Header is followed by a Pressure time series consisting of PseriesLength 3-byte unsigned integers. Each insteger will contain: For Strain-gauge raw A/D converter counts. For Serial Paros pressure in 0.001 dbars; For Druck frequency in 0.001 Hz. After the time series a 2-byte checksum is added

```
    typedef struct{
      unsigned char  SyncChar;        /* 0xA5                          */
      unsigned char  DataType;        /* 0x20                          */
      unsigned int   Nbytes;          /* In profile header             */
      char           SerialNumber[10];
      unsigned long  ProfileNumber;   /* At the start of time series   */
      DateTimeType   ProfileTime;     /* At start of time series       */

      int            SensorType;      /* 0- strain gauge               */
                                      /* 1- Paros                      */
                                      /* 2- Druck                      */
      int            PseriesRate;     /* 1/2/4  Hz                     */
```

```
    int           PseriesLength;       /* 1024/2048/4096/9192 points       */

    char          PseriesRecorded;     /* 0- No                            */
                                       /* 1- Pressure series follows this  */
                                       /*    header. 3 bytes per point     */
    char          WaveSpectraRecorded; /* 0- No                            */
                                       /* 1- Period bands computed         */

    unsigned int  WaterDepth;          /* in cm                            */
    unsigned int  Aband[12];           /* 10 period-band amplitudes in     */
                                       /*    cm, followed by significant   /
                                       /*    wave height and mean period   /
    char          Spare[20];           /* set to all 0s                    */
  }  WaveHeaderType;
```

A4. CheckSum Calculation

The ADP uses a CheckSum with each profile and whenever transmitting binary data over a serial port. The CheckSum is computed with the C function "ComputeCheckSum", included at the end of this section. To understand how the CheckSum is computed, assume that a profile has been placed in a segment of memory (i.e. a character array). The CheckSum value is stored as the last two bytes in this array. The CheckSum is computed by the following C program statement.

```
    CheckSum = ComputeCheckSum( buffer, Profile_Length - 2 );
```

In this statement, "buffer" is a pointer to the memory location where the profile begins (i.e. the name of the character array where the profile was placed). "ComputeCheckSum" adds the first "Profile_Length-2" bytes starting at location buffer, then adds the value 0xA596. The result of this summation is truncated to an unsigned two-byte integer and returned. The addition of the value 0xA596 is done so that an all-zeros profile does not produce a valid CheckSum.

```
#define CHECK_SUM_OFFSET   0xA596
unsigned int ComputeCheckSum( unsigned char *buf, int n )
{
  int i;
  unsigned int ChkSum = CHECK_SUM_OFFSET;
  for(i=0;i<n;i++) ChkSum += buf[i];
  return(ChkSum);
}
```

APPENDIX B. PC-ADP Settings and Operational Considerations

The Pulse-Coherent Acoustic Doppler Profiler (PC-ADP) is designed to support all features of a regular ADP (with the exception of bottom-tracking), and it shares similar a user interface with the ADP. However, because of fundamental differences in data processing, the PC-ADP accepts different values for some of its operating parameters and has several additional settings that are described in this appendix.

B1. PC-ADP Settings

The following sections define setting differences between the standard ADP and the PC-ADP.

B1.1. Changes to Common Settings

AvgInterval <d>   (short command "AI")
In PC-ADP mode, AI can be set between 0.5 s (2-Hz sampling) and 3600 s.

CellSize and Blanking Distance <d.dd>
Because of higher spatial resolution, the PC-ADP allows the use of smaller cell sizes and blanking distances when compared to a conventional ADP. Table B-1 summarizes the default values for blanking distance, cell size, and number of cells for each PC-ADP acoustic frequency.

Table B-1: PC-ADP variables defining profile resolution

Acoustic Frequency	Blanking Distance	Cells Size	Number of Cells
3.0 MHz	Range 0.02 - 5.0 m Default 0.02 m	Range 0.01 – 2.0 m Default 0.05 m	Range 1 – 100 Default 12
1.5 MHz	Range 0.05 - 10.0 m Default 0.05 m	Range 0.02 - 4.0 m Default 0.10 m	Range 1 – 100 Default 20
500 kHz	Range 0.20 – 30.0 m Default 0.20 m	Range 0.20 - 12.0 m Default 0.30 m	Range 1 – 100 Default 25

B1.2. Additional PC-ADP Commands and Parameters

PCMode <YES | NO>   (short command "PM")
Switches between conventional (incoherent) and pulse-coherent modes. When given without an input argument, this command returns the current setting. An input argument of NO (default) enables conventional sampling mode. An input argument of YES enables the pulse-coherent mode. When the mode settings is changed the system will load the default values (e.g.; cell size, blanking distance, etc.) that are appropriate for the chosen mode.

Pulse Lag and Velocity Range: In pulse-coherent mode, the ADP transmits pairs of pulses for each velocity profile and computes velocity as a function of range using pulse-coherent processing techniques. The velocity range of the measurements (e.g.; the maximum velocity that can be measured) depends on the time delay between the pulses (pulse lag) τ as follows:

$$U_{max} = C / 4 f \tau, \quad \text{(1)}$$

where C is the speed of sound, f is the system frequency and τ is the time between the consecutive pulses (pulse lag).

Longer lags result in smaller velocity ranges but better accuracy according to Eq (1). As such, we implement a dual-lag scheme where two pairs of pulses are transmitted, each at a different lag (Figure B-1b). The first pair has a shorter lag and is used to determine an approximate magnitude of the flow. The second pair, which has a longer lag, gives a more accurate velocity, which can be subjected to velocity ambiguity. The velocity values obtained from the first lag are then used to correct for the ambiguities that might arise. This technique results in more accuracy and is less affected by ambiguity velocity data when compared with only one lag.

When the sampling parameters are entered, the system computes the *sampling range* SR which is

$$SR = BD + CS*NC \quad (2)$$

If the specified pulse lag is smaller than the sampling range (PG<SR), the system issues a warning message and sets SR=PG. Figure B-1 describes blanking, sampling, and profiling range.

ResPulseLag <d.dd> (short command "RPG")

RPG sets the lag between the ambiguity resolution pulses (coarse velocity measurements). This parameter will ultimately determine the maximum velocity range of the measurements. The PC-ADP transmits an ambiguity resolution pulse before each profile and collects one velocity measurement in a single cell.

PulseLag <d.dd> (short command "PG")

Sets lag between the pulses for the profiling. This parameter affects velocity accuracy of the profile velocity measurements.
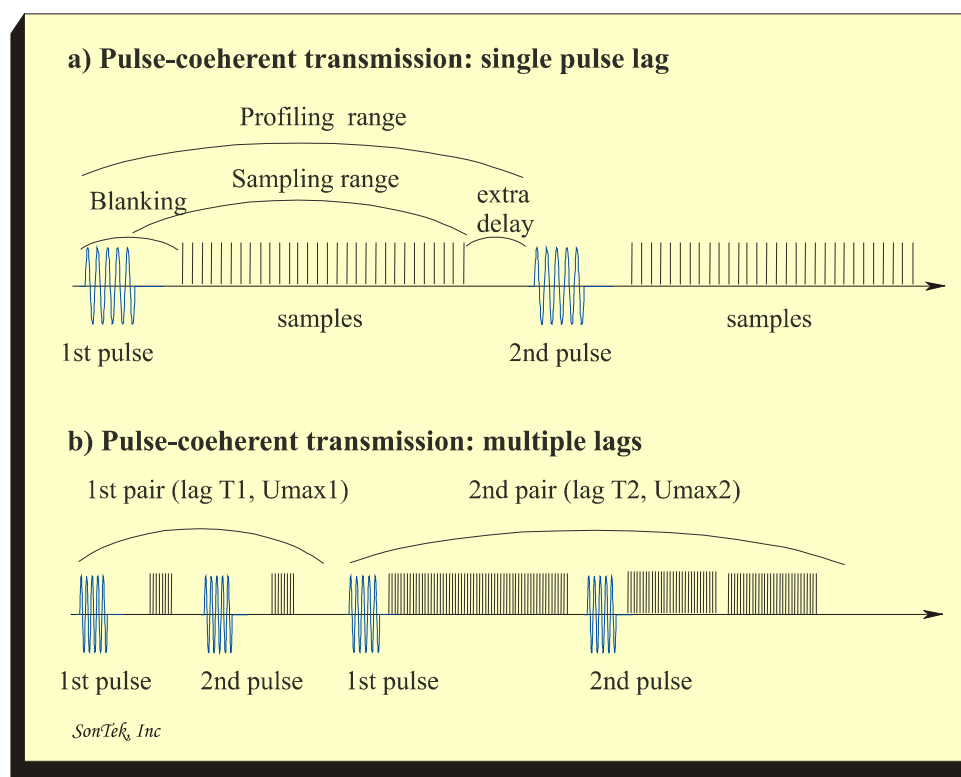
Figure B-1: Pulse-coherent processing: profiling and sampling ranges. a) single pulse pair (single lag) ; b) multiple pulse pairs (dual-lag).

MinimumCorrelationLevel <dd %> (short command "MCL")

MCL sets the minimum acceptable correlation value. During operation, the PC-ADP transmits a series of pings. The results are averaged into an accumulator and stored at the end of the averaging interval. MCL lets you set the correlations level, below which the raw samples are not included in the average. A lower MCL means more data will be accepted, a higher MCL means more data will be rejected. When given without an input argument, MCL returns the current setting. Caution: Turbulent flows can cause low correlation values, which are due to the natural variability of the flow and may be acceptable for data collection.

s setup

When pulse-coherent mode is selected, the *s setup* command will display the values of the parameters SR, PG, and MCL in addition to the regular ADP setup (see Section 3.7). It will also display the maximum vertical and horizontal velocities corresponding to the specified pulse lag according to (Eq. 2). An example of *s setup* output in pulse-coherent mode is shown below.

```
        CURRENT ADP SETUP PARAMETERS

          --------------------------
        Temp ----------- (deg C) - 20.00
        Sal ------------ (ppt) --- 34.50
        TempMode ----------------- USER
        Sound Speed ---- (m/s) --- 1520.90
        CellSize ------- (m) -----  0.05
        BlankDistance -- (m) -----  0.15
        Ncells ------------------- 30
        AvgInterval ---- (s) ----- 1.0
        ProfileInterval- (s) ----- 1.0
        CoordSystem -------------- BEAM

        Pulse Coherent Mode ------ YES
        Pulse length --- (m) -----  0.02
        Max range ------ (m) -----  1.65
        Pulse Lag ------ (m) -----  1.65
        AmbRes Lag ----- (m) -----  0.50
        MaxVertVel ----- (m/s) ---  0.77
        MaxHorizVel ---- (m/s) ---  2.98
        MinCorrLevel --- (%) -----  25
```

B1.3. Setting Up PC-ADP Mode

The following commands shows how to set up a PC-ADP in the pulse-coherent mode.

```
>PCMODE YES
```

This command tells the system to operate in PC mode and to initialize the default profiling parameters with the values shown in Table B-1. After switching to PCMODE, set the desired sampling parameters shown in Table B-2.

Other deployment parameters are set in the same way as for the regular ADP mode (see Section 3.8 for details).

To switch back to the standard ADP mode of operation use the command:

```
>PCMODE NO
```

The system will initialize the default profiling parameters with the values shown in Section 3.7.

Table B-2: Setup sampling parameters for the PC-ADP

`BD value`	Sets desired blanking distance (m)
`CS value`	Sets desired cell size (m)
`NC value`	Sets desired number of cells
`PG value`	Sets desired profiling range (if necessary)
`AI value`	Sets desired averaging interval (s)
`PRI value`	Sets desired profiling interval (s)
`CY beam`	Sets velocity coordinate system to beam; required for fast sampling with AI<10 s
`savesetup`	Stores setup parameters in the system EEPROM

B2. Considerations When Operating in PC Mode

This section discusses issues that are specific to use of the ADP in Pulse-Coherent mode.

Long Profiling Range And Short Averaging Interval

The Doppler processing techniques used by SonTek are very computation-intensive. This places some restrictions on how much data can be collected in a given time. A combination of short averaging intervals and long profiling ranges can cause situations where the system does not have enough time to complete the current profile before the next one begins. To avoid the possibility of "out of sync" data collection, a safeguard exists in PC-mode – before starting data collection, the PC-ADP collects a single profile and estimates the time required to process the data. If the total time is longer than the time between the profiles (AI), the system issues an error message asking you to reduce the profiling range or to increase the averaging interval.

Collecting Data in ENU

Conversion from XYZ to ENU coordinates is a time-consuming process. If data collection at fast rates are required, you may want to consider collecting data in XYZ coordinates instead. Because the compass reading for each profile is recorded, and because the PC-ADP is normally not subjected to significant motion during the averaging interval, velocity data can be converted to ENU coordinates in post-processing using the software provided by SonTek.

Collecting Compass Data

When averaging interval (AI) is set to less than 10-s and AI=profiling interval the PC-ADP uses a 'fast' data collection loop. As a result the heading information is not updated for each of the profile, and the values from the first profile are used throught. This is designed to maximize number of raw pings collected in the 'fast' mode. During long deployments, when the burst mode is used, the compass data are updetad at the beginning of each burst.

Collecting Pressure Time-Series

When using a short averaging interval (AI<=10s), pressure time-series collection is not supported. However, pressure is sampled and stored with every profile.

Operating Near Boundaries

The PC-ADP determines distance to the boundary at the beginning of each burst. This information can be used by the PC-ADP to adjust the lag of the pulse-coherent pulses to avoid boundary interference. Since the range to the boundary is stored within the burst header, it can be used later as an acoustic altimeter.

Data Output Mode

To increase the number of pings in the average when using a short averaging interval, we recommend you set OutMode to POLLED if a recorder is present. This will prevent single profile data from being sent to the serial port, thereby decreasing the profile overhead time.

B3. PC-ADP Operating Sequence and Data Structure

To use PC-ADP acoustic altimetry and a fast sampling rate, we recommend that burst-mode data collection be used. The PC-ADP operating sequence in the burst mode is as follows (Figure B-2):

- After DEPLOY o, is executed the system goes to sleep until the start time.

- At the beginning of each burst, the system transmits a boundary detection pulse (bottom track) and determines the distance to the boundary for each beam.

- The PC-ADP starts the profile data collection loop, which gathers data until the end of the averaging interval is reached.

- The profile data is output.

- Profiles are collected until the *Profiles Per Burst* number of profiles are collected.

- System goes to sleep until the next burst.
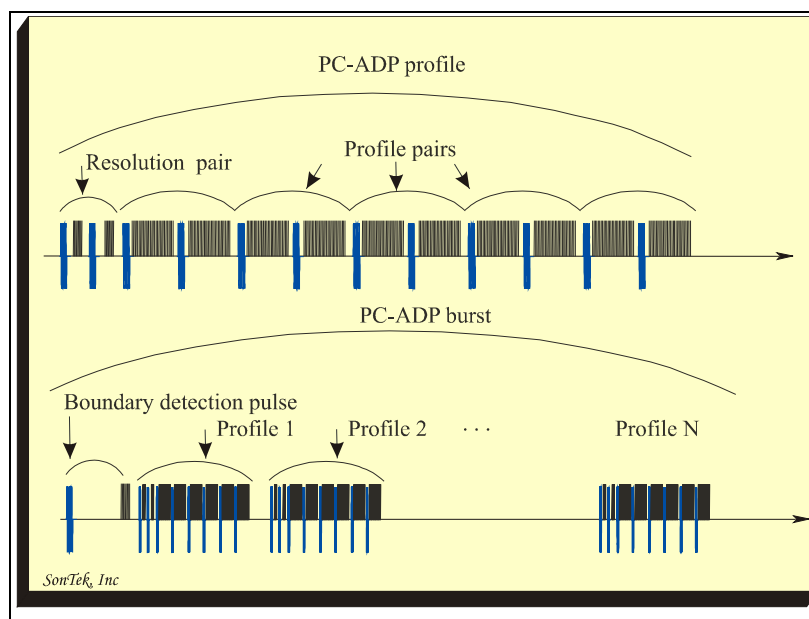
Figure B-2: PC-ADP data collection sequence

B4. PC-ADP Real-Time ASCII Data

At end of each averaging interval the PC-ADP outputs the PC-ADP data sample, which consists of the profile header, PC-record, and profile data.

Header – The information contained in the profile header (first four lines) is described below.

```
Header 1 16     DEFAULT           1 1995  1  1  3 29 31  86 3 0 0 0
Header 2 10     5     15     10     22
Header 3 0      0      0      0      0      0      0  0  0   0  15209
Header 4 0   0   0   0 122 125 127 129   7   7   7   0 152 245   0  52
```

- Header Line 1:
  data type (internal use)
  system serial number ("c23")
  profile number
  6 values for profile time (year, month, day, hour, minute, second, 100th of a second)
  number of beams (2, 3 or 4)
  orientation (0=down, 1=up, 2=side)
  temperature mode (0=user, 1=measured)
  coordinate system (0=beam, 1=xyz, 2=enu)

- Header Line 2:
  number of cells
  cell size (in cm)
  blanking distance (in cm)
  averaging interval (in 0.1 of a second)
  number of pings in this profile

- Header Line 3:
  mean heading, pitch, and roll (in 0.1°)
  mean temperature (in 0.01°C)
  mean pressure (counts)
  standard deviation of heading, pitch and roll (in 0.1°)
  std temperature (in 0.01°)
  std pressure (counts)
  sound speed (in 0.1 m/s)

- Header Line 4: This line contains system variables relating to internal system operation; the last value on the line is measured battery voltage in units of 0.2 V (i.e.; 117 = 23.4 V).

PC-Record – The information contained in the PC-Record (lines 5 and 6) is described below.

```
PC Rec 1 500    771    350    100    1650    234    150    500
PC Rec 2 0      0      0      0      53      14      29      0  1  1  1  0
```

- PC record Line 1:
  Ambiguity resolution pulse lag in mm
  Ambiguity velocity corresponding to the resolution lag (velocity range) in mm/s
  Beginning position and length (2 values) of the resolution cell in mm
  Profile pulse lag in mm
  Ambiguity velocity in mm/s corresponding and to the profile lag
  Beginning and length (2 values) of the profiling range in mm

- PC record Line 2:
  Range to the bottom for each beam (4 values) in mm
  Velocity from the resolution pulse for each beam (4 values) in mm/s
  Correlation from the resolution pulse for each beam (4 values) in %

Profile data – See Table B-3.

```
Cell 1    1     20      17      19   1   1   1   7   7   7

Cell 2    2    -87     -45     -76   1   1   1   7   7   7

...... . .

Cell 10  10      5      -5       0   1   1   1   7   7   7
```

Table B-3. ADP ASCII Output Profile Data

Column #	Contents
1	Depth cell number
2	Velocity data (V1 or Vx or Veast) in mm/s
3	Velocity data (V2 or Vy or Vnorth) in mm/s
4	Velocity data (V3 or Vz or Vup) in mm/s
5	Correlation data in %
6	Correlation data in %
7	Correlation data in %
8	Amplitude (signal strength) data (beam 1) in counts (1 count = 0.43 dB)
9	Amplitude (signal strength) data (beam 2) in counts (1 count = 0.43 dB)
10	Amplitude (signal strength) data (beam 3) in counts (1 count = 0.43 dB)

After the profile is enabled, the following data may be output as well.

OPTIONAL CTD data (if present)
```
   87514    468151       0   351354
```

OPTIONAL: Wave Record (if enabled)
```
Wave header    32 DEFAULT C23            1 1997 10 15 10 49 0 1 6 1 1 150
Pressure series 2000    2000    2000    2000    2000    2000
```

The format of the CTD, Bottom Track and Pressure series is documented in the ADP Operations Manual, Section 8.

B5. Changes to the Data Extraction Routines

The PC-ADP uses the same data extraction routines as the regular ADP with 2 exceptions: (1) In PC-MODE, the correlations (in %) are stored/extracted instead of the standard deviation (in cm/s), and (2) Additional PC-record data are extracted.

B6. PC-Record Conversion: GADPPC

This program extracts the PC header information that is recorded with each velocity profile in the pulse-coherent mode only. This information includes pulse lag, ambiguity velocity, resolution velocity, and distance to the boundary. The command format is:

```
GADPPC <ADP file>
GADPPC <ADP file> <output file>
GADPPC <ADP file> <output file> <first profile> <last profile>
```

File names must be given without extension. GADPPC generates an ASCII *output file* with the extension .PC. The program assumes that the *ADP file* has extension .ADP. If no output file name is specified, the program uses the same name as the binary data file. *First profile* and *last profile* let you extract a subset of the data. If the profile range is not specified, the program extracts all profiles in the file.

The ASCII tabular output file has one line per profile. There are no headers so that commercial processing programs (Lotus, Matlab, etc.) can easily access the data. There are 20 columns of data output in the header file. Table B-4 shows the contents and units of each column.

Table B-4. GADPPC Tabular Data Output Format

Column	Variable
1	Profile Number
2	Ambiguity resolution pulse lag in m
3	Ambiguity velocity corresponding to the resolution lag (velocity range) in cm/s
4	Beginning position of the resolution cell in m
5	Length of the resolution cell in m
6	Profile pulse lag in m
7	Ambiguity velocity in m corresponding and to the profile lag
8-9	Beginning and length of the profiling range in m
10-13	Range to the bottom (in m) for beams 1 through 4
14-17	Velocity from the resolution pulse (cm/s) for beams 1 through 4
18-21	Correlation from the resolution pulse (%) for beams 1 through 4

B7. PC-ADP Interface for LISST-100 Sensor

LISST-100 is a Laser Interferometry and Transmissometry particle distribution measurement device, designed by Sequoia Scientific. This document describes operational procedure for using LISST sensor together with the PC-ADP.

B7.1. Additional LISST-Related Commands and Parameters

LISSTSENSORINSTALLED SET <YES | NO> ()

Enables/disables LISST interface. Because LISST is a serial instrument and uses the second COM port on the PC-ADP CPU, board other serial devices (such as PAROS or Microcat CTD) must be disabled. Whenever LISSTSENSORINSTALLED is set to YES, LISSTBUFFERSIZE is set to 80 bytes (default).

LISSTBUFFERSIZE *<nbytes >* (LBS)

Sets the size of list sample buffer. If entered without an argument the command returns current settings for the LISST buffer size.

B7.2. LISST-Related Setup and Operation Sequence

The following sections describe the setup and operation sequence when the PC-ADP is used with a LISST sensor.

B7.2.1. Download LISST Control Program

The HYDRA.TTB program will need to be loaded into the LISST-100. This needs be done before connecting to the HYDRA/PCADP system. The loading is simply a transmission of the ASCII characters to the LISST-100 with occasional pauses to allow the LISST-100 to process the lines. The NEW command, (NEW <CR>), clears the current program from memory before the new program is loaded. The LIST command can be used to print the currently loaded program to the screen. TTOOLS program provided by Sequoia Scientific is best suited for this download.

- Connect LISST sensor to a serial port on your computer.

- Connect external power source to the LISST (if applicable).

- Start TTOOLS program provided by Sequoia Scientific.

- Choose Load Program (Alt-L) option under Tattletale menu and choose HYDRA.TTB file.

B7.2.2. Connect LISST to a PC-ADP

Attach the external sensor harness to the ADP electronics housing (8-pin male UW connector). Connect the LISST-100 sensor to the serial cable on the harness using LISST-CTD adaptor cable. The external cable harness is manufactured to accommodate the CTD sensor. Because the CTD and the LISST are sharing the same serial port on the ADP and have a different pin out, an adaptor cable is required to connect the LISST to the harness. Connect the external power source to the LISST (if applicable).

Connect the ADP electronics to your computer and a power source using the ADP power and communications cable. On your computer, establish communications with the ADP using *SONTERM*. In *SONTERM*, enable the LISST sensor using the LISSTSENSORINSTALLED

command. Verify that both the PAROS and Microcat CTD serial sensors are disabled. (PAROSFREQ is a frequency sensor and it can be operated simultaneously with the LISST).

Verify that you can communicate with the LISST via ADP COM port 1. To do this, issue the ECHO 1 command at the ADP command prompt. In echo mode, you can send commands and receive responses from the LISST sensor. To exit the echo mode send a break.

B7.2.3. Set Up PC-ADP for use with LISST

LISST data collection is only supported when the PC-ADP operates in burst mode. If burst mode is not enabled, and the LISST sensor option is enabled, the data collection loop will not start. The data collection sequence is as follows.

When the ADP detects the beginning of the burst interval, it tries to communicate with the LISST sensor. If communication was successful, the ADP sends the number of samples (Profiles Per Burst, PPB) and sampling rate (averaging interval) to the LISST along with a start data collection request. The ADP then proceeds with its own burst data collection loop. At the end of the burst, the ADP communicates with LISST and uploads the PPB samples. If the ADP was not able to establish communication with the LISST at the beginning or at the end of the burst, PPB blank samples are stored in the recorder to preserve the integrity of the ADP file. Note that the data upload from the LISST needs to be completed before the next burst can be initiated; this effectively increases the length of the burst. Make sure you allow for this extra time (approximately 120 s for 1,200 LISST samples) when setting the burst interval.

To set the PC-DP for data collection with the LISST:

- Set AI = PRI.

- Set Burst Mode (BM) to YES.

- Set PPB to a value between 2 and

- Set Burst Interval to be longer than (PRI * PPB) + DownLoad Time.

- Set other PC-ADP settings (PG, RPG, nCells, etc).

Initiate deployment by issuing a START or DEPLOY command. Note that if the ADP cannot establish communication with the LISST after a START or DEPLOY command is issued, the ADP will abort the data acquisition loop with an error message.

APPENDIX C. L-ADP Settings and Operational Considerations

A Lowered-ADP (L-ADP) is very similar to a regular ADP system in the way it is operated and maintained. The main difference is that the L-ADP is used for the specific application of collecting current profiles while the system is being lowered (and raised) by a cable. Most of the documentation that applies to an ADP also applies to the L-ADP. However, there are a few aspects of the L-ADP that are not covered in the general ADP manual. This appendix supplements the ADP documentation contained within this manual.

The differences between an ADP and an L-ADP are mostly in hardware – different beam angles, specialized electronics, and a specialized mode of operation (firmware). With the L-ADP mode enabled (done at the factory), you have access to a few additional commands that would normally be controlled automatically in a standard ADP. The remainder of this appendix explains L-ADP history and operation.

C1. L-ADP History

Normally, standard ADPs can only profile over ranges of up to a few hundred meters due to practical limitations in frequency (which determines acoustic propagation losses) and the size of the transducers. The L-ADP method overcomes this range limitation and permits you to obtains absolute current profiles over full-ocean depth ranges (up to several thousand meters in depth). This method was originally developed by Dr. Eric Firing at the University of Hawaii.

In the L-ADP method, one or two ADPs are lowered by cable from a surface vessel down to the desired depth (typically down to just above the bottom). During the descent, and later during the ascent, the ADP(s) continuously collect profiles of relative current velocities (relative to the instrument). Although these velocities contain the unknown, instantaneous velocity of the instrument package, the shears (dU/dz) computed within each profile are independent of instrument motion as long as accelerations are small.

By combining all the profiles collected during a down/up cast of the ADP(s), we obtain a full shear profile from very close to the surface down to the deepest point of the cast (plus one ADP profiling range). Using GPS positions of the surface vessel, this shear profile can be integrated to compute a profile of ground-referenced currents.

C2. L-ADP Package Configuration

When using the L-ADP method of casting, you would typically mounte one or two ADPs on a water-sampling Rosette. Although there is nothing that prevents the lowering of the ADPs by themselves, mounting them in Rosettes is common because many different measurements can be done simultanelously, thereby reducing operational costs and time.

The simplest configuration consists of mounting just one ADP at the bottom of the Rosette with its beams looking down. A more robust and higher-performance configuration also adds a second ADP at the top of the Rosette with its beams looking up. In addition to the ADP(s), an external battery pack is mounted on the Rosette to supply power to the instrument package. The battery pack contains rechargeable lead-acid batteries that can be recharged while the package is on deck between casts.

C3. L-ADP Operation

Compared to an ADP, the L-ADP pings faster internally (using more power) and records single-ping data (instead of long averages). This is necessary for lowered-ADP applications because the system is continually changing its vertical position while being lowered or raised.

During these down/up casts, the ADP(s) continuously collect and store velocity data to its internal recorder. Typically, the single-ping (or one-second averaged) profiles that are collected result in large amounts of data being gathered during the 2-6 hours usually needed for a deep cast.

After the instrument package is back on deck, and while the vessel moves to a new station, the data from the ADP(s) are downloaded to a personal computer, and the batteries are recharged in preparation for a new cast. The ADP data now in the personal computer are combined with GPS positions collected during the cast to produce best-estimates of absolute current profiles throughout the vertical extent of the cast.

An example of a setup for a typical cast (lowering of the system) using a 250-kHz L-ADP is shown here:

    CS 10   (10-m cell size; standard ADP command)
    NC 20   (20 cells collected per profile; standard ADP command)
    PL 10   (10-m pulse length; see Note 1)
    NPPB 4   (4 pings per beam; see Note 2)

Notes:

1. Pulse Length – This command is normally not set in a standard ADP. In a standard ADP, CS=PL. However, in an L-ADP, this parameter can be manually set by the user for this specialized application.

2. Number of Pings Per Beam – This command sets the number of raw pings averaged internally in the DSP (digital signal processor). This parameter is normally set by the system automatically (if NPPB=0, system will calculate optimum). However, with an L-ADP, the user can manually set this parameter.

3. With an L-ADP, both the PL and NPPB commands require the user to have extensive knowledge of acoustic systems and the processing of the resulting data.

4. The standard mode of operation in an L-ADP is to acquire data as quickly as possible. As such, the Averaging Interval (AI) and Profiling Interval (PRI) commands are disabled. Although you are able to change AI and PRI in the setup, the values are ignored by the L-ADP during data collection. The rate at which the L-ADP outputs data can be controlled by the NPPB command. Although the rate at which the instrument profiles is dependent on the number of cells (NC) and the cell size (CS), a 250-kHz L-ADP with a standard setup will output approximately one profile per second when NPPB is set to 4 (averages 4 pings together in the DSP before storing the data).

In L-ADPs, CPU usage and data handling tasks are processor-intensive. As such, we recommend that you turn off data output to the serial port. Turning off the serial port output lets the system collect data faster. The command to turn off the port is: OM POLLED.

C4. Dual L-ADP Synchronization

One typical configuration of a dual L-ADP system is to mount one system pointing in the upward direction and the second system pointing in the downward direction (see Section 4 for information on how to change instrument orientation). The two L-ADPs and the battery housing are already wired for synchronization of the systems. One wire goes through cables/battery housing to connect the sync ports of both L-ADPs. To control the level of synchronization (synchronization mode), a new parameter (SyncMode) must be used:

SyncMode <DISABLE | MASTER | SLAVE>   (short command "SM")

Argument definitions:

- DISABLE – The ADP will operate independently and ping as quickly as possible.

- MASTER – The ADP will send a sync signal to any slaves just prior to starting a ping.

- SLAVE – The ADP will wait for a sync signal to arrive before starting a new ping.

Considerations when using the MASTER/SLAVE mode:

- The duration of a ping in the SLAVE must not be longer than the duration of a ping in the MASTER. Therefore, in the case of a multi-frequency arrangement, we recommend that the 250-kHz system be set as the master, and the 500-kHz system be set as the slave (i.e.; the lower frequency system is the master and the higher frequency is the slave).

- The sync protocol requires adding some delays in both the MASTER and the SLAVE so that the pinging rate will be slower in this configuration (about 30% slower). If the systems are working independently, they should be set to DISABLE so that they can achieve maximum pinging rate.

- NPPB should be set to 1 when using MASTER/SLAVE. The reason for this is that synchronization occurs only at the first ping in a NPPB sequence.

- When using synchronization, you should "START" the slave first, and then the master. This will assure a one-to-one corresondence from ping number 1.

C5. Bottom-Tracking and L-ADPs

Due to the nature of the L-ADP system, and the requirement for the system to ping as rapidly as possible, the L-ADP does not bottom track. A traditional bottom-track would cause the L-ADP to ping slower because of the system's need to switch between bottom-track pulses and water-track pulses throughout the entire cast (the system is only within the range of the bottom for a brief time relative to the rest of the cast).

C6. Additional Information about L-ADP Applications and Operation

More details about processing L-ADP data and the setup of these specialized instruments can be found on the Internet with L-ADP user groups and web sites dedicated to the operation and data processing of these systems. An example of one of these web sites that is available to the general public is: *http://www.ldeo.columbia.edu/~visbeck/ladcp*.

C7. Rechargeable L-ADP Battery

The L-ADP has significant power demands. As such, the L-ADP uses rechargeable gel-cell batteries that have significant instantaneous current capability. The general guidelines included

below must be followed to ensure that the system continues to work properly. The following procedures are for a typical charging scheme. It is important that the batteries are kept as close to full-charged as much as possible to ensure good battery performance for many casts.

1. When disconnecting and re-connecting the L-ADP to the battery pack, be sure to perform the connections in the following order:
   Connecting: Connect the cable to the L-ADP <u>before</u> connecting it to the battery housing.
   Disconnecting: Disconnect the cable from the battery housing <u>before</u> you disconnect it from the L-ADP.

> **WARNING: Severe damage to the system can occur if the above procedure is not followed.**

2. Dry the lid of the battery canister and the area around the vent, being certain that there is no water around seat of the vent plug. Open the vent plug in the top of the battery canister using the supplied hex driver (key). Be certain not to allow water from the surrounding environment to enter into the vent hole at any time.

> **WARNING: Severe damage or explosion can occur if the above procedure is not followed.**

3. Plug the power/communication/charge cable into the center 8-pin, wet-mateable connector in the top of the battery canister. Plug the charger into the mating 3-pin DIN plug. Plug the charger into an AC source. The state of the batteries will determine the amount of current the charger will drive the batteries with. It should be noted that due to losses in cables longer then 50 meters, the charger will be unable to fully charge the batteries. To fully charge the batteries, use cables shorter than 50 meters.

4. While the system is charging, you can use the system as necessary to perform tasks such as downloading data or system configuration for the next deployment. The charger provided will automatically limit the current going to the battery depending on the battery status. Therefore, we suggest that the batteries be charged between each of the deployments.

5. Before a deployment, you should remove power to the charger, be certain the vent plug is clean, apply grease to the O-ring, and fully tightened the vent.

6. When you are certain that the above steps have been completed, the system can be set up and deployed. After the power and communication cable is removed, make sure the connector is replaced with a well-greased dummy plug (be certain that all unused exposed connectors are plugged with well-greased dummy connectors). *It is extremely important that you are certain all power is removed from the power/communications cable before it is disconnected from the battery pack.*

> **WARNING: SEVER DAMAGE TO THE ENTIRE SYSTEM WILL OCCUR IF IT IS DEPLOYED WITHOUT THE VENT PLUG IN THE BATTERY CANISTER FULLY CLOSED!**

A YSI Environmental Company

Acoustic Doppler Profiler (ADP®)
Software Manual
Version 6.42

ADP (Acoustic Doppler Profiler) is a registered trademark of SonTek/YSI, Inc.

INTRODUCTION

Thank you for buying an ADP from SonTek. Included with your ADP is Software Version 6.42 or later, which is designed to provide a powerful and flexible means to control instrument operation and access data. All software is written for DOS on PC-compatible computers. The software is intended to be easy to use, and it is our hope that the manual should be needed only as a reference.

This manual is divided into the following sections.

- **Section 1 Software Summary**
A listing of all programs supplied with Software Version 6.42 and their function.

- **Section 2 Real-Time Data Collection (ADPSA)**
This program collects ADP data when connected directly to a PC-compatible computer. It provides a menu driven format for selecting ADP operating parameters and a graphical display of ADP data.

- **Section 3 Binary Data Conversion (GADP___)**
These programs extract data from ADP binary data files into easily accessible ASCII files.

- **Section 4 Compass Calibration (COMPCAL)**
This program calibrates the internal compass/tilt sensor to eliminate contamination from ambient magnetic fields.

- **Section 5 Terminal Emulator (SONTERM)**
This program is for direct communication with the ADP.

- **Section 6 Recorded Data Extraction (SONREC)**
This program downloads ADP data files from the internal recorder.

- **Section 7 Additional Support**
This section provides contact information for additional customer support.

- **Appendix A Automatic File Naming Convention**
This appendix describes the file naming convention (based upon date and time) used when automatic file recording is specified in the real-time data collection software.

- **Appendix B Correcting for Vessel Motion Using GPS Position Data**
This appendix provides the algorithms to compensate ADP velocity data collected from a moving vessel by calculating vessel speed from GPS position data.

TABLE OF CONTENTS

SECTION 1.   Software Summary

This section gives a summary of all programs provided with the ADP Software Version 6.42. The software includes programs for real-time data collection, data conversion, compass calibration, recorder data extraction, and direct communication with the ADP. A list of the files on the diskette, with a description of their basic function, is shown below.

- README   ASCII text file containing a summary of the programs on the diskette.
- ADPSA.EXE   Real-time data collection (see SECTION 2).
- COMPCAL.EXE   Compass calibration (see SECTION 4).
- GADPAMP.EXE   Data conversion programs. These extract different portions of
  GADPCTL.EXE   ADP data from the binary files to an easily accessible ASCII
  GADPGPS.EXE   format (see SECTION 3).
  GADPHDR.EXE
  GADPSNR.EXE
  GADPSTD.EXE
  GADPVEL.EXE

Extraction programs for using with ADP optional features:
- GADPBT.EXE   (Described in Part 5)
  GADPCTD.EXE   (Part 5)
  GADPPRES.EXE   (Part 5)
  GADPWAVE.EXE   (Part 5)

- MAGDEC   A useful utility, which provides compass magnetic declination at a specified position and time (SECTION 7)
- SONREC.EXE   Recorder data extraction (see SECTION 7).
- SONTERM.EXE   Terminal emulator (see SECTION 5).

Additionally, the diskette includes a directory called SOURCE. This directory contains source code, written in C, for all ADP data conversion routines (the GADP___.EXE files). This code allows the user to easily write their own software to access the ADP binary data files. The code should be easily understandable to anyone with basic experience programming in C.

SECTION 2.   Real-Time Data Collection (ADPSA)

This program collects data from an ADP in real time. The software must be run from DOS on a PC-compatible computer with a minimum 33-MHz 386 processor, 640K RAM, VGA graphics, and a hard disk. It provides a menu driven format to select ADP data collection parameters, real-time display of the velocity data, and writes the ADP data to binary files on the computer hard disk.

The program has two primary display screens: setup and data acquisition. The setup screen is for selecting ADP operating parameters. The data acquisition screen provides a graphical display of ADP data, as well as tabular information relating to data collection and recording. The description of the real-time data collection software is divided into the following sections.

- Section 2.1 gives an overview of program operation.
- Section 2.2 shows command line options to modify program operation.
- Section 2.3 describes the ADPSA setup screen.
- Section 2.4 describes the ADPSA data acquisition screen.
- Section 2.5 discusses using ADPSA to integrate GPS position data with ADP velocity data.
- Section 2.6 describes the contents of ADP binary data files.
- Section 2.7 describes configuration and log files used with ADPSA.

2.1.   Program Overview

When run with no command line options, ADPSA will first try to communicate with the ADP on COM1 at 9600 baud (different communication parameters can be specified using command line options; see section 2.2). If communication is established, it downloads the current hardware and user parameters and enters the setup screen.

If communication cannot be established, ADPSA loads the hardware configuration file specified in the ASCII text file ADPSENS.DEF. ADPSENS.DEF is a text file with one line naming the hardware configuration file to be used. For example, if ADPSENS.DEF contains the following line:

```
ADP4050.SEN
```

this specifies the configuration file ADP4050.SEN for serial number 4050. The hardware configuration file allows the user to enter the setup screen without being connected to the ADP. When using these files, the program outputs a message that communications were not established and then enters the setup screen. The hardware configuration file and ADPSENS.DEF are included on the software diskette.

In the setup screen, the user can modify operating parameters, view hardware configuration and performance estimates, specify a recording file name, and start data collection. When data collection is started, the program sends all user settings to the ADP, enters the data acquisition screen, and begins collecting data. Within the data acquisition screen, the user can modify the graphical display without affecting data collection or recording.

IMPORTANT: At the start of data collection, the ADP internal clock is set to match the computer clock. This time standard is applied on all recorded data.

2.2.   Command Line Options

Several command line options can alter the operation of ADPSA and change communication settings. Options designated by a single letter (c, f, g, p, w) change the operation of the data acquisition program; multiple-character options change how the program communicates with the ADP.

The table below gives the command line options that can modify the operation of ADPSA. Multiple command line options can be given in any combination. When more then one option is selected, all options should be given together (i.e. "ADPSA –cg" or "ADPSA –gp").

ADPSA Command Line Options

Command	Function
ADPSA –c	Command file. This causes the program to send all commands in the user-generated ASCII text file USERCONF.CMD to the ADP prior to entering the setup screen. Thus, the parameters shown in the setup menu will reflect the settings given by commands in USERCONF.CMD.
ADPSA –f	Automatic file recording. This option causes the program to automatically select a file name for recording to the computer hard disk. See below for details on the file naming convention.
ADPSA –g	Automatically start data collection. This causes the program to skip the setup screen and immediately begin data collection. The ADP will use the data collection parameters stored in internal memory in the ADP. This option includes automatic file recording. This command can be put at the end of the AUTOEXEC.BAT file and collection will resume after a power failure.
ADPSA –p	Integrate GPS position data. This allows the program to read GPS position data from an available serial port and integrate the position data with the ADP data files. GPS position data can compute absolute velocity data when the ADP is installed on a moving vessel. See below for details on using the –p option; see sections 2.5 and 3.5 for more details on using integrated GPS position data.
ADPSA –w	Black and white display. This option is useful on portable computers being operated outdoors.

Automatic file recording

When using the automatic file-recording feature (-f or -g), the user must create the file ADPFILE.DEF to specify details relating to data file recording. This is a one-line ASCII text file, an example of which is shown below.

```
C:\ADP\AA   HOURLY
```

The first word specifies the path ("C:\ADP\") for the data file and the first two characters ("AA") in the file name. The remainder of the file name is generated using the date and time (see Appendix A). The second word on this line specifies the interval at which new data files are created. This is either done at the start of each hour (HOURLY) or when the file reaches a

particular size (SIZE <kBytes>). For example, "C:\ADP\AA SIZE 1400" will create a new file each time the data file reaches 1400 kBytes.

Integrated GPS position data

Using the –p command line option allows ADPSA to integrate GPS position data into the file. See sections 2.5 and 3.5 for more information about using GPS position data to correct ADP velocity data from a moving vessel. When using integrated GPS data, the user must create a one-line ASCII text file named "GPSPORT.DEF" to specify the format of the GPS data and the serial communication parameters used. The basic format of this file is shown below.

```
<Message Format> <com port> <baud rate> <parity> <data bits> <stop bits>
```

Where

- <Message Format> is the GPS message format being used. The ADP software will interpret three different types of GPS data formats: "$GPGXP" and "$GPGGA" $GPGGK".
- <com port> is the serial port number to which the GPS receiver is connected (1 for COM1 or 2 for COM2). This must be different than the port to which the ADP is connected.

  NOTE: Default DOS/WINDOWS serial port COM1 and COM2 configuration be used:
  COM1 Interrupt request (IRQ)- 04, Input/output range 03F8-03FF
  COM2 Interrupt request (IRQ)- 03, Input/output range 02F8-02FF
  Communication ports configured using different settings (even though designated as COM1 or COM2) will not operate.

- <baud rate> is the baud rate setting of the GPS data. Acceptable baud rate settings are 4800, 9600 and 19200.
- <parity> is the parity setting: N for no parity, O for odd, and E for even.
- <data bits> is the number of data bits: 7 or 8.
- <stop bits> is the number of stop bits: 1 or 2.

The following line is an example of the GPSPORT.DEF file when inputting GPS data in the $GPGXP format on COM 2 at 4800 baud, no parity, 8 data bits, and 1 stop bit.

```
$GPGXP 2 4800 N 8 1
```

Integrating GPS data with the ADP data file provides an additional option in the data acquisition screen of ADPSA. Velocity data can either be displayed relative to the ADP (without using the GPS data) or absolute currents subtracting the vessel speed based upon GPS position data. See Section 2.4 for more details.

Combinations of command line options

Many of the command line options shown above can be given in combination to increase the flexibility of the data collection software. For example, the command "ADPSA –cg" combines the command file and auto start options. When this command is selected, the program will send the commands specified in the ASCII file USERCONF.CMD to the ADP. It will then immediately begin data collection with a recording file named based upon date and time. The command "ADPSA –cgp" adds integrated GPS position data to the above operation. Placing one of these commands at the end of the AUTOEXEC.BAT file will automatically re-start data collection in the event of a power failure.

<u>Communication settings</u>

Using the default settings, ADPSA will communicate with the ADP on COM1 at 9600 baud. The following options can modify the communication port settings.

```
COM1, COM2
BR1200, BR2400, BR4800, BR9600, BR19200, BR38400, BR57600, BR115200
```

For example, the following command will run ADPSA with automatic file recording using serial port COM2 at 4800 baud.

```
ADPSA -f -COM2 -BR4800
```

The communication settings can be used individually or in combination with any of the other command line options. Each communication option should be listed separately on the command line as shown above; the order in which command line options appear is not important.

2.3.   Setting up Data Acquisition Parameters

Unless run with the -g command line option (automatic start), ADPSA enters the setup screen after loading hardware and user configuration parameters. An example of this screen is shown in Figure 1. The screen is divided into three areas. The top right corner shows the computer date and time. The center right portion of the screen presents ADP hardware configuration information and performance estimates based upon the current operating parameters. The left side of the screen has a number of active windows to select operating parameters for the ADP.

<u>Computer date/time</u>

The computer date and time are shown in the upper right hand corner of the screen. It is important to note that this is the date and time used for data collection by ADPSA. The ADP internal clock is set to match the computer clock, and all data has a time stamp that matches the computer clock.

<u>Hardware configuration and performance estimate</u>

Hardware configuration parameters are normally downloaded from the ADP. If the program is unable to establish communication with the ADP, it will load the hardware configuration from the file specified in the text file "ADPSENS.DEF" (see section 2.1). The first item under hardware configuration (ADP Status) reflects whether the program was able to establish communication with the ADP. Sensor serial number and system frequency are values that are factory set for each ADP. Sensor orientation (for UP / DOWN / SIDE profiling) is set by a hardware switch on the ADP electronics. Changing sensor orientation also requires the user to modify the installation of the compass/tilt sensor; see the ADP Operation Manual for details.

Three parameters relating to ADP performance are calculated based upon the current hardware and operating parameters. Upper and lower profile depths are calculated based upon cell size, blanking distance, number of cells, sensor orientation, and sensor mounting depth. They represent the lower edge of the lower cell and the upper edge of the upper cell, respectively. In the data acquisition screen, velocity data are plotted based upon the location of the center of each cell. Velocity precision is an estimate of the accuracy of the velocity measurements based upon

the cell size and averaging interval (the number of cells can also affect this value if it affects pinging rate).

2.3.2. User setup parameters

The left portion of the setup screen displays a number of parameters that can be set by the user for each deployment. To change these parameters, move through the items using the up/down arrow keys (or page up/page down). Information about the highlighted parameter is displayed at the bottom of the screen. The current item (highlighted) is changed or executed by pressing the ENTER key. After pressing the ENTER key on a highlighted item, the user is prompted to enter a new value for the parameter, or to choose from a set of acceptable values. If a parameter is accidentally selected the user may recover by pressing the ESC key, leaving the parameter unchanged.

A description of each item in the user setup menu is given below.

Water Temperature (°C): (Enter value)
Temperature is required for calculating the speed of sound, which converts Doppler shift to water velocity. The entered temperature may or may not be applied for sound speed calculations depending upon the temperature mode setting (see below).

Figure 1 – ADPSA Setup Screen

Water Salinity (ppt): (Enter value)
Salinity is used to calculate the speed of sound, which converts Doppler shift to water velocity.

Speed of Sound (m/s): (Derived value)
The speed of sound in water is given in the menu for information only, and cannot be changed by the user. It is computed from the values of temperature and salinity. Sound speed shown in this menu is based upon the entered values of temperature and salinity; if temperature mode is set to MEASURED, the sound speed will be based upon the value from the ADP temperature sensor. See the ADP Principles of Operation for details on the effect of sound speed on ADP operation.

Temperature Mode: (Multiple-choice)
Temperature mode refers to the source of temperature data for sound speed calculations. USER indicates that the value input in the setup menu (see above) should be used; MEASURED indicates that the value from the ADP temperature sensor should be used. The ADP temperature sensor is considered sufficiently reliable and accurate ($\pm 0.2°C$) for sound speed calculations, thus MEASURED is the common choice. The USER setting is occasionally selected to simplify post-processing corrections using data from an external temperature / salinity sensor. Sound speed is recorded with each profile, so post-processing corrections can be made using data from either temperature mode.

Averaging Interval (s): (Enter value)
The ADP will accumulate samples internally for this period of time and then display and store the mean current profile. The standard deviation (accuracy) of the velocity data is inversely proportional to the square root of the averaging interval (longer averaging times give lower standard deviations).

Number of Depth Cells: (Enter value)
Number of depth cells to collect per profile.

Depth Cell Size (m): (Enter value)
Vertical length of each depth cell. Standard deviation (accuracy) of the velocity measurements is inversely proportional to the depth cell size (larger depth cells give lower standard deviations).

Blanking Distance (m): (Enter value)
The vertical distance from the transducers to the start of the first depth cell. A minimum value is required for each frequency to avoid contamination. Except for specialized applications, the blanking distance should be left at the minimum setting and not changed by the user. Minimum values for each frequency are shown in the table below.

ADP Minimum Blanking Distances

Frequency	Minimum Blanking Distance
3000 kHz	0.2 m
1500 kHz	0.4 m
1000 kHz	0.5 m
750 kHz	0.8 m
500 kHz	1.0 m
250 kHz	1.5 m

Coordinate system: (Multiple-choice)
This determines the coordinate system in which velocity data are displayed and stored. BEAM gives velocity data as along-beam velocities (not common). XYZ gives velocity data in a Cartesian coordinate system relative to ADP orientation (see the ADP Operation Manual). ENU (for East-North-Up) reports data in an instrument independent Earth coordinate system; this option requires that the ADP have the optional compass/tilt sensor installed. When configuring the ADP, be certain that "Sensor Orientation" is correctly set in the hardware configuration, as this will affect the reporting of velocity data in either the XYZ or ENU coordinate system. For most applications, the ENU coordinate system is preferred.

Sensor Mounting Depth (m): (Enter value)
This sets the depth at which the ADP is mounted (at the level of the transducer faces). This value is for display purposes to determine the depth of each cell.

Magnetic Variation (deg): (Enter value)
The difference between magnetic north and true north, expressed as degrees east of true. Thus a value of 10.0 indicates magnetic north is 10° east of true north, where as a value of -10.0 indicates that magnetic north is 10° west of true north. This value is for display purposes only when using the ENU (East-North-Up) coordinate system; display velocities are rotated to represent true north. The data stored in binary files are always referenced to magnetic north when using the ENU coordinate system.

> NOTE: in order to obtain up to date magnetic variation (declination) for your specific location use utility MAGDECL (see SECTION 7) provided with the ADP software package.

Bottom Track (Yes or No):
Enables disables the Bottom Tracking mode.

Record Pressure Series (value) (Enter value)
Controls Collection/Recording of the Pressure Series data. When RPS=N (N>0) is entered the pressure data will be collected every N profiles (note, that the time between successive pressure records will be N×PRI, where PRI is profiling interval in s). If N=0 is specified, no pressure data is collected.

Pressure Series Length (samples) (Enter value)
Sets the length of the pressure time series (in samples). The PSL should fall in the range between 1 and 8192 samples. The length of the pressure series in seconds equals PSL/PSR.). Because the wave extraction software uses 256-second data segments it is recommended that the PSL is a multiple of that number. For more accurate wave parameter estimation we also recommend the minimum pressure series length of 1024 seconds. However the user may choose smaller values if desired.

Pressure Series Rate (Hz) (Enter value)
Specifies the sampling rate for the pressure time series collection (can be set to only 1, 2 or 4 Hz).

Record To File: (Enter filename)
This item assigns a file for recording ADP data. Several checks have been incorporated to insure that a valid filename is given, the file can be created, and that an existing file is not accidentally overwritten.

File Comment 1/2/3: (Enter text)
These items permit the user to enter up to three 60-character lines of text for the purpose of documenting the data set.

START Data Acquisition: (Enter)
Once the user is satisfied with the setup, data acquisition can be started by pressing Enter on this item. The program will initialize the ADP and enter the data acquisition mode.

EXIT Data Acquisition: (Enter)
Pressing Enter causes the program to terminate and return to DOS.

2.4. Data Acquisition Display

After selecting "Start Data Acquisition" in the setup screen, the program displays the command sequence for initializing the ADP, and then switches to the real-time display and the ADP begins collecting data. Figure 2 shows an example of the data acquisition screen. The top of the screen displays information on the status of data acquisition. The main portion of the screen provides a graphical data display of ADP data. The bottom of the screen shows which keys are active during data acquisition and the function of each.

2.4.1. Status Information

The status portion of the screen is updated with each profile; each block is described below.

Recording To File
This displays the path and name of the ADP data file. If recording is disabled, the words NOT RECORDING are displayed.

File Size (kb) / Disk Space (kb) / Recording Time Left (h)
These fields will display information only if recording is enabled. "File Size" gives the current size of the data file in kilobytes. "Disk Space" gives the amount of space left on the disk on which the data file resides (also in kilobytes). "Recording Time Left" tells the user how many hours of data can be collected at the present rate before the disk becomes full.

Start Time
This time is obtained from the computer clock (note that the ADP clock is set to match the PC clock at the start of data collection) and represents the start of the first averaging interval.

Profile Time
This represents the time of the profile currently displayed on the screen (start of the averaging interval).

Secs to Average
Indicates the time remaining (in seconds) in the current averaging interval.

Profile Number
This is the number of the last velocity profile collected and currently displayed.

Heading / Pitch / Roll
These fields present data from the optional compass/tilt sensor.

Temp (°C)
Displays the most-recent data from the ADP temperature sensor.

Pressure (dB)
Displays the most-recent data from the optional ADP pressure sensor, in dBar. This field will show 0 if the pressure sensor is not installed.

Bottom Track Display (if enabled)
Displays the most-recent bottom-track data: averaged depth (m), Veast and Vnorth (cm/s).

GPS Navigation Display (if present)
Displays the most-recent position (Lat & Long) and vessel spees (Veast and Vnorth (cm/s)).

Waves Display (if enabled)
Displays the most-recent wave data: Significant wave height (H_{mo}, cm) and wave peak period (T_p, s).

External CTD Display (if present)
Displays the most-recent data acquired from an external CTD: temperature (°C), conductivity {Siemens), pressure {dbar) and salinity, (ppt).).
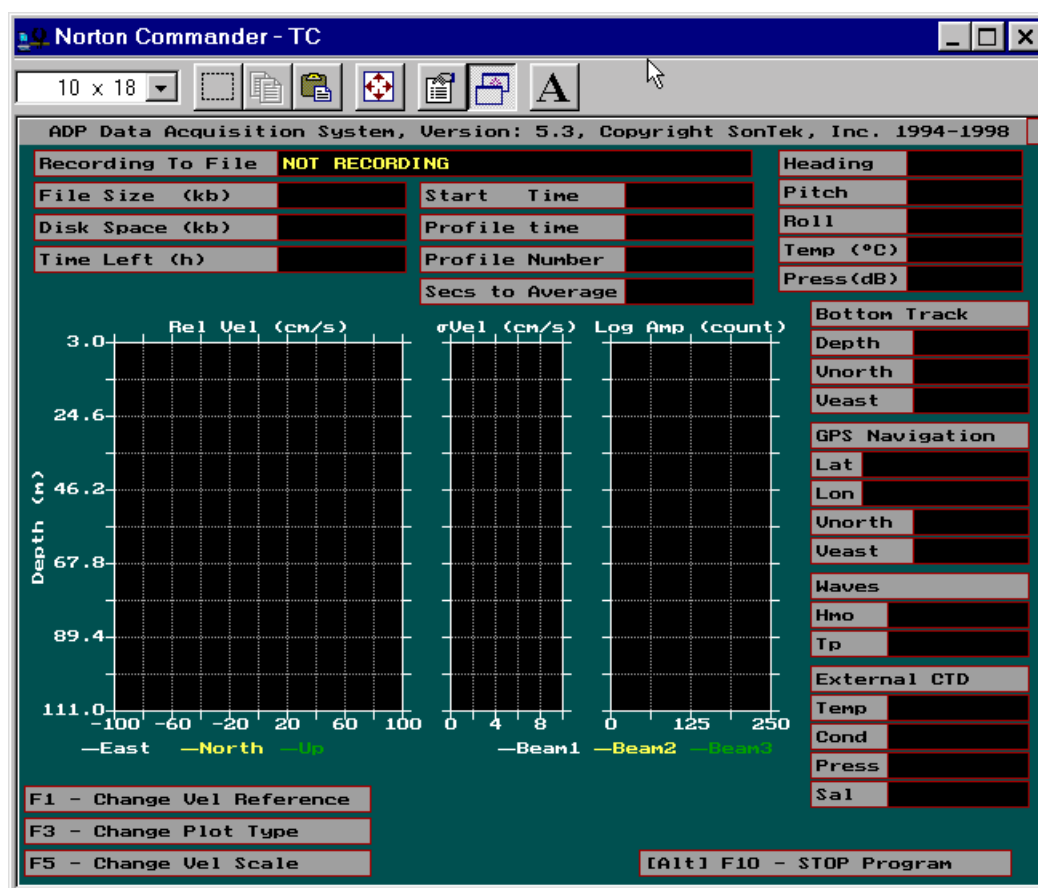

Figure 2 – ADPSA Real-Time Data Acquisition Display

2.4.2. Velocity Profile Data

The data acquisition mode has two graphical displays: one presents velocity component data in BEAM, XYZ, or ENU coordinates, and the other gives current speed and direction. The plots associated with each display type are described below.

Velocity component plots: (shown in Figure 2)
The first plot ("Vel (cm/s)") displays the most-recent velocity profile with separate lines for each velocity component (either Beam 1/2/3, X/Y/Z, or East/North/Up). The second plot ("σVel (cm/s)") displays the standard deviation of each velocity component. For all plots, the (Beam 1/X/East) component is shown in white, (Beam 2/Y/North) in yellow, and (Beam 3/Z/Up) in green.

The third plot ("Log Amp (count)") displays the acoustic signal strength as a function of depth for each of the three acoustic beams. Signal strength is the magnitude of the return signal from the water, and is a function of the frequency of the ADP, the amount of scattering material in the water, and the range from the instrument. Signal strength is plotted using internal units called counts; one count equals 0.43 dB. See the ADP Principles of Operation for more information about interpreting ADP velocity, standard deviation, and signal strength.

Current speed and direction plots:
The first plot ("Speed (cm/s)") displays the most-recent profile of water speed, and the second plot ("Direction") displays the most-recent profile of water velocity direction. Only horizontal velocity data are used for the calculation of speed and direction (X and Y, or East and North, depending upon the coordinate system selected). The units for direction are degrees clockwise from north for the ENU coordinate system, or degrees clockwise from the positive Y-axis for the XYZ coordinate system. The third plot ("Log Amp (counts)") displays the acoustic signal strength, as described above. This display type is not allowed if the BEAM coordinate system is selected.

2.4.3. Control Keys

Three active keys may be used during data collection. The first two keys (F3 and F5) affect only the graphical display and do not alter or interrupt data collection. The third key (ALT+F10) stops data collection (it prompts you to confirm before stopping). Pressing the ESC key will remove the pop up window if any key is pressed unintentionally.

F3 - Change Plot Type: (Multiple-choice)
Pressing the F3 key permits the user to select the type of graphical display.
"Beam, XYZ or ENU" plots the velocity data as individual components. "Speed / Dir" plots the velocity data as current speed and direction.

F5 - Change Vel Scale: (Multiple-choice)
Pressing the F5 key permits the user to select the full scale of the velocity profile plot. Velocity scale options are: ±10 cm/s, ±20 cm/s, ±50 cm/s, ±100 cm/s, ±200 cm/s, ±300 cm/s, and ±500 cm/s. Note that this setting affects both types of graphical displays (velocity component and current speed), but does not affect recorded data.

[ALT] F10 - Stop Program: (Yes/No)

To stop data acquisition, the user must press the ALT and F10 keys simultaneously. After this is done, the user is presented with a prompt (a Yes/No multiple-choice window) to confirm the intention to stop the program. Data collection/recording proceeds normally until the confirmation is given. Upon selecting "Yes", the program returns to the setup screen. If the program was run with the automatic start option ("ADPSA -g"), confirmation after ALT-F10 returns to the DOS prompt.

F1 – Change Vel Reference: (Multiple-choice)
This allows the user to select how ADP velocity data are displayed. "Relative to ADP" gives the raw velocity relative to the instrument. "Relative to GPS" uses the GPS calculated vessel speed and the magnetic variation (from the setup menu) to determine the absolute water velocity, independent of vessel motion.

If ADPSA has been run with the –p option for integrated GPS data, there will be several minor changes in the data acquisition screen. Several additional fields will be present in the status portion of the screen, and one additional active key is enabled. Each of these is described below.

2.4.4. Integrated GPS Data

If ADPSA has been run with the –p option for integrated GPS data, there will be several minor changes in the data acquisition screen. Several additional fields will be present in the status portion of the screen, and one additional active key is enabled. Each of these is described below.

Latitude / Longitude
These fields display the most-recent position information from the incoming GPS data.

Vessel Speed (knots)
These fields give the north-south and east-west vessel speed from the last profile, calculated based upon GPS position data.

F1 – Change Vel Reference: (Multiple-choice)
This allows the user to select how ADP velocity data are displayed.
"Relative to ADP" gives the raw velocity relative to the instrument.
"Relative to GPS (if present)" uses the GPS calculated vessel speed and the magnetic variation (from the setup menu) to determine the absolute water velocity, independent of vessel motion.
"Relative to Bottom (if enabled)" uses the Bottom Track speed and the magnetic variation (from the setup menu) to determine the absolute water velocity, independent of vessel motion.

2.5. Considerations When Collecting GPS Data

Integration of GPS position with ADP velocity data allows the instrument to measure absolute current profiles from a moving vessel. This is a very powerful capability, particularly for performing rapid current surveys over a wide area. However, the user must be aware that collecting data from a moving vessel is inherently more complex than from a stationary system. Extra precautions are required to ensure good quality data. Several areas of concern are described below.

Positioning Data

The accuracy of the positioning data is an essential key to the success of moving boat data collection. A good quality GPS receiver with accurate differential corrections should be used. The accuracy of the positioning data directly determines the accuracy of the absolute velocity profiles. For example, if the positioning data has an uncertainty of ±2 m and an averaging interval of 60 seconds is entered, the uncertainty of the vessel speed for each profile is about ±6 cm/s. This uncertainty is reflected directly in the absolute current speed.

Compass Data

The quality of heading, pitch, and roll data is equally critical. The importance of accurate heading is magnified because of the vessel motion. For example, if data are being collected from a boat moving at 5 knots, a heading error of 2° translates into a cross-track velocity error of (5 knots * $\sin(2°)$ = 8 cm/s). Before starting data collection, perform a compass calibration with the ADP mounted in the exact location and orientation that it will be in during data collection. Additionally, limit vessel speed to reduce the effect of any heading errors.

Magnetic Variation

The value for magnetic variation entered in the setup menu rotates ADP velocity data from magnetic East-North-Up coordinates to geographic East-North-Up. This is required since GPS data yield vessel speed in geographic coordinates. The accuracy of magnetic variation therefore affects the accuracy of absolute velocity data, with the same sensitivity as heading data discussed above. In order to obtain up to date magnetic variation (declination) for your specific location use utility MAGDECL provided with the ADP software package.

Operating Parameters: Cell Size and Averaging Interval

In moving boat applications, you will typically use a larger cell size than stationary applications. There are several reasons for this: higher vertical resolution is not meaningful because of motion of the vessel (heave, pitch, roll, and translation), larger cell sizes achieve lower instrument noise in a short period of time, and the maximum profiling range of the system is typically important. Recommended cell sizes for the different ADP frequencies are 0.5 m, 1.0 m, 1.0 m, 2.0 m, 4.0 m, and 4.0 m for the 3000 kHz, 1500 kHz, 1000 kHz, 750 kHz, 500 kHz, and 250 kHz, respectively.

Moving boat velocity data typically require relatively large averaging times (5-10 minutes) to reduce the effects of boat motion. However, for flexible post processing we recommend recording data with a shorter averaging interval (1 minute) and performing the additional averaging in post processing. This allows you to precisely define different segments of the data (i.e. on station versus in motion) and gives the greatest flexibility in data analysis.

General Data Processing Concerns

As mentioned before, the user should be aware of the increased complexity of moving boat data collection. SonTek is willing to provide support, guidance, and software to assist in collecting and analyzing moving vessel ADP data. However, the user will also need to invest time in understanding the different aspects of moving boat data collection and in developing the tools needed for effective data analysis.

2.6.   Data Recording

ADP data are recorded in a standard binary file format; the same format is used whether data are recorded using ADPSA or on the internal recorder. When data collection is started, the hardware configuration and user operating parameters are stored in a file header structure. With each profile, the system stores a binary record containing velocity, signal strength, standard deviation, heading, pitch, roll, profile time, and a number of other parameters. All of the data contained in these files can be accessed by the data conversion programs discussed in SECTION 3. The binary file format is described in detail in the ADP Operation Manual.

When using ADPSA to collect data, the user has the option to also store data internally on the ADP recorder. ADPSA does not affect any ADP settings that relate to the internal recorder; these are left in the same state during data collection, as they were when ADPSA was started. The most common reason to use the internal recorder while collecting data with ADPSA is for a backup in case of computer malfunction or power loss. To do this, the user should use a terminal emulator (i.e. SONTERM.EXE) to set the ADP recorder to ON and the recorder mode to BUFFER. In BUFFER mode, the internal recorder will overwrite the oldest data currently on the recorder once all available space has been filled.

2.7.   Associated Configuration and Log Files

There are several configuration and log files associated with the operation of ADPSA.

ADPSA Associated Configuration and Log Files

File Name	Function
ADPSA.LOG	Records all communication between computer and ADP in an ASCII text file; this file is overwritten each time ADPSA is run. Information recorded here can be useful when looking for errors in data collection.
ADPUSER.SET	Records settings for all user parameters; overwritten each time ADPSA is exited. This binary file is only used if the computer is unable to communicate with the ADP upon start up.
DISPLAY.SET	This binary file records the most-recent graphics settings from data acquisition mode.
ADPSENS.DEF	This text file specifies which hardware configuration file is used if needed (see section 2.1).
*.SEN	Hardware configuration file (see section 2.1).
USERCONF.CMD	This ASCII text file is used with the -c command line option (see section 2.2).
ADPFILE.DEF	This ASCII text file is for automatic file recording with the -f or -g command line options (see section 2.2).
GPSPORT.DEF	This ASCII text file is used with the –p command line option (see sections 2.2 and 2.5)

SECTION 3.   Binary Data Conversion (GADP___)

All binary data files generated by the ADP, whether collected using the real-time data collection software ADPSA or recorded internally in ADP memory, use the same format. The exact format of the binary data files is given in the ADP Operation Manual. The data conversion software discussed in this section extract various portions of the data from the binary file to an easily manipulated ASCII format. The following list summarizes these programs and their functions. These programs can be run on any PC-compatible computer.

- GADPAMP   Extracts raw signal strength data.
- GADPCTL   Extracts configuration and setup information.
- GADPHDR   Extracts profile header information (heading, pitch, roll, temperature, and pressure) recorded with each velocity profile.
- GADPSNR   Extracts Signal-to-Noise Ratio (SNR) data.
- GADPSTD   Extracts velocity standard deviation data.
- GADPVEL   Extracts velocity data as individual components (BEAM, XYZ, or ENU).

The following program is used only if the ADP data files contain GPS position data collected using the real-time data acquisition software (see section 2.5).

- GADPGPS   Extracts GPS position data.

The following programs are used only if the ADP data files contain corresponding optional data collected using the real-time data acquisition software (see corresponding sections of Section 8 in Operations Manual).

- GADPCTD   Extracts CTD data.
- GADPBT   Extracts Bottom Track data.
- GADPPRESS   Extracts Pressure Time Series.
- GADPWAVE   Extracts wave spectra.

If the name of any of these programs is entered by itself, the program will display information on its usage and a description of the parameters that can be specified on the command line.

3.1.   Control File Conversion: GADPCTL

GADPCTL extracts configuration and setup information from the binary data files. This includes all header data recorded only once with each file. It is selected by entering either of the commands below.

```
GADPCTL <ADP data file>
GADPCTL <ADP data file> <output file>
```

File names must be given without extension. The program assumes that the ADP data file has extension .ADP and assigns the output data file the extension .CTL. For example,

```
GADPCTL TEST HEADER
```

will extract the configuration information from ADP binary data file TEST.ADP and place it into an ASCII file named HEADER.CTL. If <output file> is not specified, the program will create an

---

output file with the same name as the ADP data file (i.e. TEST.CTL). The information in the .CTL file is in a self-explanatory ASCII text format.

3.2. Profile Header Conversion: GADPHDR

This program extracts the header information that is recorded with each velocity profile. This information includes time, heading, pitch, roll, temperature, pressure, and sound speed. The file will show 0 for any data where the optional sensor is not installed (i.e. compass or pressure sensor). The command format is as follows.

```
GADPHDR <ADP file>
GADPHDR <ADP file> <output file>
GADPHDR <ADP file> <output file> <first profile> <last profile>
```

File names must be given without extension. GADPHDR generates an ASCII output file with the extension .HDR. The program assumes that the ADP data file has extension .ADP. If no output file name is specified, the program uses the same name as the binary data file. First profile and last profile permit the user to extract a subset of the data. If they are not specified the program extracts all profiles in the file.

The ASCII tabular output file has one line per profile. There are no headers so that commercial processing programs (Lotus, Quattro Pro, Matlab, etc.) can easily access the data. There are 20 columns of data output in the header file; the table below shows the contents and units of each column.

GADPHDR Tabular Data Output Format

Column	Contents	Units
1	Profile number in file	
2	Profile time (start of averaging interval) - Year	
3	Profile time (start of averaging interval) - Month	
4	Profile time (start of averaging interval) - Day	
5	Profile time (start of averaging interval) - Hour	
6	Profile time (start of averaging interval) - Minute	
7	Profile time (start of averaging interval) - Second	
8	Number of samples averaged for this profile	
9	Sound speed to calculate velocity	m/s
10	Mean heading	degrees
11	Mean pitch (rotation about the Y axis)	degrees
12	Mean roll (rotation about the X axis)	degrees
13	Mean temperature	°C
14	Mean pressure	dBar
15	Standard deviation of heading	degrees
16	Standard deviation of pitch	degrees
17	Standard deviation of roll	degrees
18	Standard deviation of temperature	°C
19	Standard deviation of pressure	dBar
20	Instrument power supply voltage level	V

3.3.   Profile Data Conversion: GADPAMP / SNR / STD

These five programs extract different portions of the ADP profile data from the binary files: signal strength (as the log of the return signal amplitude), signal to noise ratio (SNR), current speed and direction, standard deviation, and velocity. Each program operates using under the same command protocol.

```
GADP____   <ADP file>
GADP____   <ADP file> <output file>
GADP____   <ADP file> <output file> <first profile> <last profile>
```

File names must be given without extension. The programs assume that the ADP data file has extension .ADP. If no output file name is specified, the programs use the same name as the binary data file. Specifying the first and last profile permits the user to extract a subset of the data. If they are not specified, the programs extract all profiles in the file.

Each program generates several multiple ASCII tabular data files. The output files generated by each program are listed below.

- GADPAMP creates files with extension ".A1", ".A2", and ".A3" corresponding to signal strength for beams 1, 2, and 3, respectively.
- GADPSNR creates files with extension ".SN1", ".SN2", and ".SN3" corresponding to SNR for beams 1, 2, and 3, respectively.
- GADPSTD creates files with extensions ".SD1", ".SD2", and ".SD3" corresponding to the standard deviation of velocity components based upon the coordinate system selected (Beams 1, 2, and 3 / Vx, Vy, and Vz / VEast, VNorth, and VUp).

These programs generate tabular data files with one line per profile. The first value in each line is the profile number within the data file. This is followed by the measurement at each depth cell in the profile, starting with cell 1 (closest to the transducer). The range from the instrument to the center of each cell is given in the ASCII file generated by GADPCTL. This range can also be calculated by the following formula.

Range = Blanking_Distance + (Cell_Number*Cell_Size)

The units for each of these programs are shown in the table below.

Profile Data Units

Program	Units
GADPAMP	counts (see explanation below)
GADPSNR	decibels (dB) (see explanation below)
GADPSTD	cm/s
GADPVEL	cm/s (degrees clockwise from Y-axis (XYZ coordinates)) or (degrees from magnetic north (ENU coordinates)) for direction

For signal strength data, GADPAMP uses internal ADP units called counts; one count equals 0.43 dB. GADPSNR extracts the signal to noise ratio of the ADP. This is the signal strength minus the system noise level, converted to dB. SNR (Signal-to-noise ratio) data determines maximum profiling range (see ADP Principles of Operation).

If ADP signal strength is being used to estimate sediment concentration, raw signal strength data from GADPAMP should be used rather than SNR, since the latter includes information about the instrument noise level, which may change with time. Further references on the use of ADP data for monitoring sediment concentration are available upon request.

For more information about how to use each type of ADP data, see the ADP Principles of Operation.

3.4.   Velocity Data Conversion: GADPVEL

This program extracts velocity data from an ADP data file and writes them to an ASCII file in tabular format. GADPVEL creates files with extensions ".V1", ".V2", and ".V3" corresponding to velocity components based upon the coordinate system selected (Beams 1, 2, and 3 / Vx, Vy, and Vz / VEast, VNorth, and VUp). The command syntax is as follows.

```
GADPGPS <ADP file> [options]
```

where:

- <ADP data file>   is the name of an ADP binary data file (no extension).

[options]   is one or more of the following optional parameters:

- <-Oname>   Name of output file (no extension). Defaults to input file name.

- <-Nj:k>   Extracts profiles numbered j to k. Default is all profiles.

- <-Mddd.d>   Magnetic declination. Default is MagDecl stored with data. (Note: only the real-time program allows the inclusion of magnetic declination).

- <-Ccoordsys>   Change output coordinates to XYZ (-CXYZ) or ENU (-CENY). Default is to output data in whatever coordinates they were collected.

- <-AAbsVel>   Convert to absolute velocities relative to GPS (-AGPS) or to bottom (-ABOT). Default is to output velocities relative to ADP. Note: Absolute velocities relative to GPS can only be used in the ENU system.

- <-SPDR>   Output velocities as magnitude and direction.

File names must be given without extension. The program assumes that the ADP data file has extension .ADP. If no output file name is specified, the program uses the same name as the ADP data file. Specifying the first and last profile permits the user to extract a subset of the data. If they are not specified, the program extracts all profiles in the file.

Example:
```
GADPVEL  test1  -O\data\test1 -M11.3 -N1:200 -CENU -AGPS
```

will extract velocity profiles 1 to 200, from file test1 and output velocity relative to GPS into a file \data\test1 using magnetic variation of 11.3°, in ENU coordinates.

3.5. GPS Data Conversion: GADPGPS

The program provide access to the GPS position data recorded when the real-time data collection software is run with the "ADPSA –p" option (see sections 2.2 and 2.5 for details). Each record extracted contains the profile number, and the universal time, latitude and longitude for the first and last GPS message during an averaging interval. This program can only be used if GPS position data are included in the file. The command format is as follows.

```
GADPGPS <ADP file> [options]
```

where:

- <ADP File> is the name of an ADP binary data file (no extension).

- [options] is one or more of the following optional parameters:

    - <-Oname> Name of output file (no extension). Defaults to input file name.

    - <-Nj:k> Extracts profiles numbered j to k. Default is all profiles.

File names must be given without extension. The program assumes that the ADP data file has extension .ADP. If no output file name is specified, the program uses the same name as the ADP data file. Specifying the first and last profile permits the user to extract a subset of the data. If they are not specified, the program extracts all profiles in the file.

Example:
```
GADPGPS   test1  -O\data\test1 -N1:200
```

Will extract GPS data for the profiles 1 to 200, from file test1 and output data into a file \data\test1.

GADPGPS generates one ASCII output file with the extension .GPS. The ASCII tabular output file has one line per profile with 7 columns of data as described in the table below.

GADPGPS Tabular Data Output Format

Column	Contents
1	Profile number in file
2	UTC time from start of profile (seconds from January 1, 1980, 00:00:00)
3	GPS Latitude from start of profile (positive for degrees North)
4	GPS Longitude from start of profile (positive for degrees East)
5	UTC time from end of profile (seconds from January 1, 1980, 00:00:00)
6	GPS Latitude from end of profile (positive for degrees North)
7	GPS Longitude from end of profile (positive for degrees East)
8	GPS East Velocity
9	GPS West Velocity
10	GPS Velocity Magnitude
11	GPS Velocity Direction

SECTION 4.   Compass Calibration (COMPCAL)

This program is provided with the ADP software to allow the user to calibrate the internal compass/tilt sensor. Calibration minimizes the effects of ambient magnetic fields on compass data. We recommend that a compass calibration be performed before each deployment.

This program gives a graphical display of instrument orientation that can insure the compass/tilt sensor is functioning correctly. The program is intended to be self-explanatory; simply type "COMPCAL" at the DOS prompt for operating instructions. To run the calibration program, make sure that the instrument is powered up and connected to a computer serial port and type one of the following commands:

```
COMPCAL <com port>
COMPCAL <com port> <baud rate>
```

where

- <com port> is the serial port number to which the ADP is connected (1 for COM1 or 2 for COM2).
- <baud rate> is the communication baud rate setting of the ADP; if no value is given, the program assumes the default setting of 9600 baud. Acceptable baud rate settings are 1200, 2400, 4800, 9600, 19200, 38400, 57600, and 115200.

Once started, the program shows a graphical display of compass orientation. At this point, the compass is not in calibration mode; it is in a monitoring mode where orientation data is output in real time. The graphical display provides three perspectives. To the right is a compass that indicates the direction the X-axis is pointing. To the left are tabular and graphical displays of pitch and roll. In the center is a 3D box with an X on the side corresponding to north. When this side is facing into the screen, the instrument X-axis is facing north.

To begin the calibration, press the F1 key. The program will pause to put the compass in calibration mode; following this, the display will resume and the program provides instructions for instrument rotation at the bottom of the screen. Rotate the instrument slowly through two complete circles, while varying the pitch and roll as much as possible. Each turn should take about one minute; the exact starting and ending orientations are not important.

To end the calibration, either press the F1 key again (to remain in the graphical display) or press the ESC key to exit with the calibration results. Pressing ESC at any time during this program will exit the program and display the results of the most-recent calibration. Refer to the ADP Operation Manual for more information about compass calibration and for information on how to interpret the calibration score.

SECTION 5.   Obtaining Correct Magnetic Variation (MAGDECL)

In order to facilitate correct measurements of velocity direction SonTek supplies utility MAGDECL.EXE which provides access to a magnetic variation database MAGDATA.GRD.

This program computes the magnetic declination of Earth's magnetic North as a function of Date, Latitude and Longitude. Magnetic Declination is the horizontal angle between the Magnetic North and TRUE North. For example, a declination of +10 deg means that Magnetic North is 10 deg to the East of TRUE North. SonTek's ADP, ADV, and ARGONAUT systems use a

magnetic compass to measure the direction of North, which results in velocities referenced to magnetic North instead of TRUE North. Magnetic Declinations permit to correct these velocities so that they are referred to TRUE North.

The program usage is as folows:

```
MAGDECL <Date> <Latitude> <Longitude>
```

where:

- <Date> is in the format yy/mm/dd.

- <Latitude> is in decimal degrees (from -90 to 90)

- <Longitude> is in decimal degrees (from -180 to 180)

Example:
```
MAGDECL  97/10/24 32.7 -117.2
```

Since magnetic variation is not only a function of the exact position but also the time it is advised that the user obtains an up to date magnetic variation before setting up a deployment. Although the Earth magnetic field slowly changes, for most latitudes (away from poles) the rate of change is very small so a few days, or even months, only cause a fraction of a degree change.

SECTION 6.   Terminal Emulator (SONTERM)

This program is for direct communication with the ADP over a computer serial port. To run the program type "SONTERM" at the DOS prompt. Direct communication with the ADP is used for a variety of functions including system diagnostics, autonomous deployment, manual recorder-data retrieval, and placing the system in sleep mode. Refer to the ADP Operation Manual for more details about the direct command interface.

To establish direct communication with the ADP, simply connect the cable from the instrument to COM1 of your computer, supply power to the ADP, and run SONTERM. Press "ALT+B" to send a BREAK and establish communication. The ADP will respond with a message similar to "SonTek ADP, Copyright 1997…" and will then return a command prompt (">").

SONTERM displays user commands in yellow type and instrument output in blue type. There are several active keys for special functions within SONTERM, as shown in the first table below. One function, ALT+S, enables the user to change communications settings; details of this are shown in the second table. The default settings match the default communication parameters of the ADP.

SONTERM Function Keys

Key	Function
ALT+B	Sends a BREAK over the serial port. This involves holding the computer transmit data line high for a period of 500 milliseconds. The BREAK causes the ADP to terminate any operations (or exit the sleep mode) and enter the command mode.
ALT+F	Open or close a log file. If no log file is currently open, the program prompts the user to enter a file name; everything that appears on the screen will be written to this file. If a log file is currently open, this function closes the file. When SONTERM is first started, no log file is used. Confirmation is required before the program will overwrite an existing log file.
ALT+C	Loads commands from an ASCII file. The user is prompted to enter the file name. The file specified should be an ASCII text file with each line containing one command for the ADP. The program reads the commands from the specified file and sends them in order to the ADP. This is useful to ensure that a precise series of commands are sent to the ADP.
ALT+S	Set communication parameters, such as serial port number and baud rate. Refer to the table below for details.
ALT+X	Exit the program.

To change communication parameters within SONTERM, press "ALT+S". This gives a menu with a number of active keys to set the communication port, baud rate, parity, number of data bits, and number of stop bits. The default baud rate is 9600 baud; this can be changed using hardware switches in the ADP processor (refer to the ADP Operation Manual). The fixed communication parameters are no parity, 8 data bits, and 2 stop bits; these are the default settings in SONTERM. The table below shows the active keys to set all available values for these

parameters. When the desired parameters have been set, press ESC to return to normal SONTERM operation. The most-recent parameter settings are saved to the computer hard disk and used when running SONTERM.

Changing Communication Parameters (ALT+S)

Parameter	Keystroke and Function		
Communication port	F1 - COM1	F2 - COM2	
Baud rate	1 - 300 2 - 1200 3 - 2400	4 - 4800 5 - 9600 6 - 19200	7 - 38400 8 - 57600 9 -115200
Parity	N - none E - even	O - odd H - high	L - low
Data bits	Alt+F7 - 7	Alt+F8 - 8	
Stop bits	Alt+F1 - 1	Alt+F2 - 2	
Defaults	D - Return all settings to default values (COM1, 9600 baud, no parity, 8 data bits, 2 stop bits)		

SECTION 7. Recorder Data Extraction (SONREC)

This program extracts data from the optional ADP internal recorder. To learn about its operation, type "SONREC" at the DOS prompt.

IMPORTANT: This program should be run from a dedicated DOS environment, not from a DOS prompt within Windows. Memory resident features of Windows interfere with serial port operation. Running this program from within Windows will at the very least slow down data retrieval, and can potentially cause the retrieval to fail.

To run from the DOS prompt, use one of the following commands.

```
SONREC <com port>
SONREC <com port> <baud rate>
SONREC <com port> <baud rate> <extraction rate>
```

where

- <com port> is the serial port number to which the ADP is connected (1 for COM1 or 2 for COM2).
- <baud rate> is the communication baud rate setting of the ADP; if no value is given, the program assumes the default setting of 9600 baud. Acceptable baud rate settings are 1200, 2400, 4800, 9600, 19200, 38400, 57600, and 115200.
- <extraction rate> is the baud rate at which data files will be retrieved from the recorder; if no value is given, it uses the default setting of 115200 baud. Acceptable extraction rate values are 1200, 2400, 4800, 9600, 19200, 38400, 57600, and 115200.

For example, the command "SONREC 1 9600 38400" will establish communication with the ADP on COM1 at 9600 baud and download data files using 38400 baud.

For short cables (less than 30 m), the default extraction rate of 115200 baud provides the fastest downloading time. For longer cables, a slower baud rate may be needed to ensure reliable communication (if you are regularly downloading large files on a long cable, it may be worthwhile to switch the ADP to RS422 serial communication). If SONREC encounters a large number of communication errors while retrieving data, it will terminate the retrieval. Note that some computers (particularly older laptop computers) do not operate reliably at high baud rates and may not be able to work using the default setting of 115200. If you encounter problems with SONREC, run the program using a lower extraction rate.

The table below shows the typical download rates achieved with different baud rate settings. Extraction rates slower than 9600 baud are rarely needed and are not shown here.

SONREC Data Retrieval Rates

Extraction rate	Effective retrieval rate	Download time for 1 MB
115200	4800 bytes per second	3.6 minutes
57600	3400 bytes per second	5.1 minutes
38400	2600 bytes per second	6.7 minutes
19200	1500 bytes per second	11.5 minutes
9600	850 bytes per second	20.5 minutes

Upon execution, SONREC wakes the ADP and establishes a direct link to the recorder at the specified extraction rate. The program then downloads the directory of files stored on the recorder and displays this information on the screen. The directory screen shows the following information.

- Number of files on recorder
- List of files including name, size, and date/time of creation.
- Recorder size (bytes)
- Recorder free space (bytes)
- Extraction baud rate
- Active keys and their function, as listed below
  - ESC - exit program
  - SPACE BAR - mark and unmark files for extraction
  - F3 - retrieve all marked files
  - DEL - format the recorder and erase all data

Within SONREC, move between files in the directory using the up/down arrow and page up/down keys. The SPACE BAR will mark and unmark one or more files for retrieval. Pressing F3 retrieves all currently marked files. The program prompts you to enter a destination path for the files; if no path is given, the current directory is selected. While retrieving data files, the program provides ongoing information about progress with each file.

SONREC transmits data from the recorder in blocks, each of which includes a checksum for reliable data transmission. If the checksum fails, the program will attempt to transmit the same block again. If the program encounters a large number of errors during retrieval, it will abort the process. Try running the program again at a lower data extraction rate.

Pressing the DEL key will format the recorder and delete all data files. Before the files are deleted, the user is prompted to enter the complete word "Yes" for confirmation. Be certain that all data are backed up before erasing the recorder. Data cannot be recovered after formatting the recorder. Pressing ESC will exit the program.

Data files extracted from the ADP recorder are assigned the extension .ADP.

SECTION 8. Additional Support

Any additional questions can be directed to SonTek by phone, FAX, or e-mail. Regular business hours are 8:00 am to 5:00 p.m., Pacific Standard Time, Monday through Friday.

Phone	(858) 546-8327
Fax	(858) 546-8150
Email	inquiry@sontek.com
World Wide Web	http://www.sontek.com

See our web page for information concerning new products and software / firmware upgrades. SonTek also maintains an FTP site for software upgrades and data exchanges. To access the FTP site, login anonymously to *ftp.sontek.com*, use your e-mail address as a password, and use the path */pub*.

The FTP site includes a directory called "incoming", which has external write privileges and will accept incoming files. Note that there are no external read privileges for this directory, so you will not be able to view this file after sending it to this directory. After sending the file, notify us by phone, fax, or e-mail and we will look at the data as soon as possible.

There are a number of other directories on the FTP site providing upgrades, demonstration software, and a variety of other information. In each directory there is a file called "0README" that provides information on what information is available and where to find it.

APPENDIX A. Automatic File Naming Convention

When automatically generating data file names in the real-time software (running ADPSA with the -f or –g command line options), the ADP uses a file naming convention based upon the date and time at which the file was created. Unless the clock has been reset such that two files are started within the same minute, the file name cannot be repeated. An example of this convention is shown below.

AA7ADM23.ADP

where

AA = starting two characters as specified in the file ADPFILE.DEF (see section 2.2).
7 = last digit of year (199**7**)
A = month (i.e. A = 10 = October)
D = day (i.e. D = 13)
M = hour (i.e. M = 22)
23 = minute
.ADP = all ADP data files use the same extension

The above file name is for a file started at 22:23 on October 13, 1997. Several tables showing the abbreviation for month, day and hour are shown below.

Month

1 = January	4 = April	7 = July	A = October
2 = February	5 = May	8 = August	B = November
3 = March	6 = June	9 = September	C = December

Day

1 = 1	5 = 5	9 = 9	D = 13	H = 17	L = 21	P = 25	T = 29
2 = 2	6 = 6	A = 10	E = 14	I = 18	M = 22	Q = 26	U = 30
3 = 3	7 = 7	B = 11	F = 15	J = 19	N = 23	R = 27	V = 31
4 = 4	8 = 8	C = 12	G = 16	K = 20	O = 24	S = 28	

Hour

0 = 0	3 = 3	6 = 6	9 = 9	C = 12	F = 15	I = 18	L = 21
1 = 1	4 = 4	7 = 7	A = 10	D = 13	G = 16	J = 19	M = 22
2 = 2	5 = 5	8 = 8	B = 11	E = 14	H = 17	K = 20	N = 23

APPENDIX B. Correcting for Vessel Motion Using GPS Position Data

The ADP real-time data collection, when run with the "ADPSA –p" command line option, allows integration of GPS position with ADP velocity data. Good quality differential GPS position data can be used to compensate velocity data measured from a moving vessel to compute the absolute current.

This appendix provides the algorithms to calculate vessel motion from GPS data, and to remove vessel motion from ADP velocity data. These algorithms are used for the display of absolute velocity data in the real-time software (see sections 2.4 and 2.5), and for the output of absolute velocity data in ASCII format using the data conversion software (see SECTION 3).

GPS position and time data is recorded at the beginning and end of each profile. Calculating vessel motion based upon GPS data is done using the following steps.

- Convert latitude, longitude, and height (assumed to be 0) to an earth-centered, earth-fixed XYZ coordinate system.
- Calculate the position change in the XYZ coordinate system from position data at the beginning and end of the profile.
- Convert the change in the XYZ coordinate system to a position change in the local ENU (East-North-Up) coordinate system based on latitude and longitude.
- Calculate vessel motion (east and north components) from the change in ENU position and the change in GPS time.

ADP velocity data (relative to the instrument) is compensated for vessel speed using the following steps.

- Rotate ADP velocity data from magnetic East-North to geographic East-North using the magnetic variation.
- Subtract vessel speed from ADP velocity.

The following C language code performs these steps. This is included (in a slightly different format) with the ADP software as part of the data conversion software source code.

```
typedef struct
{
  long   Utc;    /* Universal time of position fix (GPS sec) */
  double Lat;    /* In degrees                               */
  double Lon;    /* In degrees                               */
} GpsPosType;

GpsPosType  StartGpsPos;
GpsPosType  EndGpsPos;
float       GpsVnorth;
float       GpsVeast;

/*===========================================================*/
/*   LlhXyz                                                  */
/*   Given the lat, lon and height of point on earth this    */
/*   function computes the earth centered coordinates for    */
/*   that point.                                             */
/*   Notes: Heights must be in m. x,y,z are returned in m    */
/*                                                           */
#define dtr   0.1745329251994330E-1 /* Degrees to radians    */
```

```
#define Ae    6378137.0           /* Earth's semi-major axis */
#define Flat  0.0033528107        /* Earth's flattening      */

void LlhXyz(double Lat, double Lon, double Height, double xyz[])
{
  double rlat, rlon, clat, slat, clon, slon, g1, g2, g3;

  rlat = dtr*Lat;
  rlon = dtr*Lon;
  clat = cos(rlat);
  slat = sin(rlat);
  clon = cos(rlon);
  slon = sin(rlon);
  g1 = Ae/sqrt(1 - (2 - Flat)*Flat*slat*slat);
  g2 = g1*(1 - Flat)*(1 - Flat) + Height;
  g3 = (g1 + Height)*clat;

  xyz[0] = g3*clon;
  xyz[1] = g3*slon;
  xyz[2] = g2*slat;
}
/*===========================================================*/
/*    XyzToEnu                                               */
/*  Given a vector in the earth centered, earth fixed        */
/*  coordinate system, and a position lat/lon on the surface */
/*  of the Earth, this funtion will compute the components   */
/*  of that vector in the local East/North/Up system.        */
/*                                                           */
void XyzToEnu(double Lat, double Lon, double xyz[], double Enu[])
{
  double rlat, rlon, clat, slat, clon, slon;

  rlat = DegToRad(Lat);
  rlon = DegToRad(Lon);
  clat = cos(rlat);
  slat = sin(rlat);
  clon = cos(rlon);
  slon = sin(rlon);
  Enu[0] = -xyz[0]*slon +       xyz[1]*clon;
  Enu[1] = -xyz[0]*slat*clon - xyz[1]*slat*slon + xyz[2]*clat;
  Enu[2] =  xyz[0]*clat*clon + xyz[1]*clat*slon + xyz[2]*slat;
}
/*===========================================================*/
void ComputeGpsVel( void )
{
  int i,j,k,l,m,n;
  double dxyz[3], denu[3], dt;
  double xyz0[3], xyz1[3];

  LlhXyz(StartGpsPos.Lat, StartGpsPos.Lon, 0.0, xyz0 );
  LlhXyz(EndGpsPos.Lat,   EndGpsPos.Lon,   0.0, xyz1 );

  for(i=0;i<3;i++) dxyz[i] = xyz1[i] - xyz0[i];

  XyzToEnu(StartGpsPos.Lat, StartGpsPos.Lon, dxyz, denu);

  dt = EndGpsPos.Utc - StartGpsPos.Utc;
  if(dt < 0) dt += 604800.0;   /* correct for week crossover */

  if(dt >= 1)
  {
    GpsVeast  = denu[0] / dt;
```

```
    GpsVnorth = denu[1] / dt;
  }
}

/*===========================================================*/
void ComputeAbsVelocities(void)
{
  int i,j,k,l,m;
  float ar, ca, sa;
  int nbins = AdpUser.Ncells;

      /* convert magnetic variation (east of north) to radians */
  ar = DegToRad(DisplaySetup.MagneticVariation);
  ca = cos(ar);
  sa = sin(ar);

      /* correct velocity in all bins                         */
  for(i=0; i < nbins; i++)
  {
      /* ADP velocity is rotated for magnetic variation       */
      /* Prf.Vel[0][i] is magnetic east, Prf.Vel[1][i] is north*/
      /* vertical velocity (Prf.Vel[2][i]) is not affected    */
      /* recall that velocity is stored as mm/s               */
AbsVel[i][0] = ca*Prf.Vel[0][i] + sa*Prf.Vel[1][i] + 1000*GpsVeast;
AbsVel[i][1] =-sa*Prf.Vel[0][i] + ca*Prf.Vel[1][i] + 1000*GpsVnorth;
AbsVel[i][2] =  Prf.Vel[2][i];
}
}
```

Acoustic Doppler Profiler (ADP®) Principles of Operation

Table of Contents

ADP (Acoustic Doppler Profiler) is a registered trademark of SonTek/YSI, Inc.

1. Introduction

The SonTek Acoustic Doppler Profiler (ADP) belongs to a group of instruments known as acoustic Doppler current profilers (ADCPs).

- Since the 1980s, ADCPs have become established as the preferred method for measuring currents in the open ocean.
- Since its introduction in 1994, the ADP has expanded the use of ADCPs into shallow water applications.
- The ADP is the first ADCP designed specifically for shallow-water applications, reducing cost and improving performance for coastal areas, estuaries, lakes, and rivers.

This document presents the operating principles of the ADP. It does not attempt to provide a detailed discussion of all technical issues, nor a detailed description of ADP operation. To learn more about specific applications, please contact SonTek.

2. The Doppler Shift

The ADP measures the velocity of water using a physical principle called the Doppler effect.

- If a source of sound is moving relative to the receiver, the frequency of the sound at the receiver is shifted from the transmit frequency.
- For Doppler current meters, we look at the reflection of sound from particles in the water.
- The change in frequency is proportional to the velocity of the water.
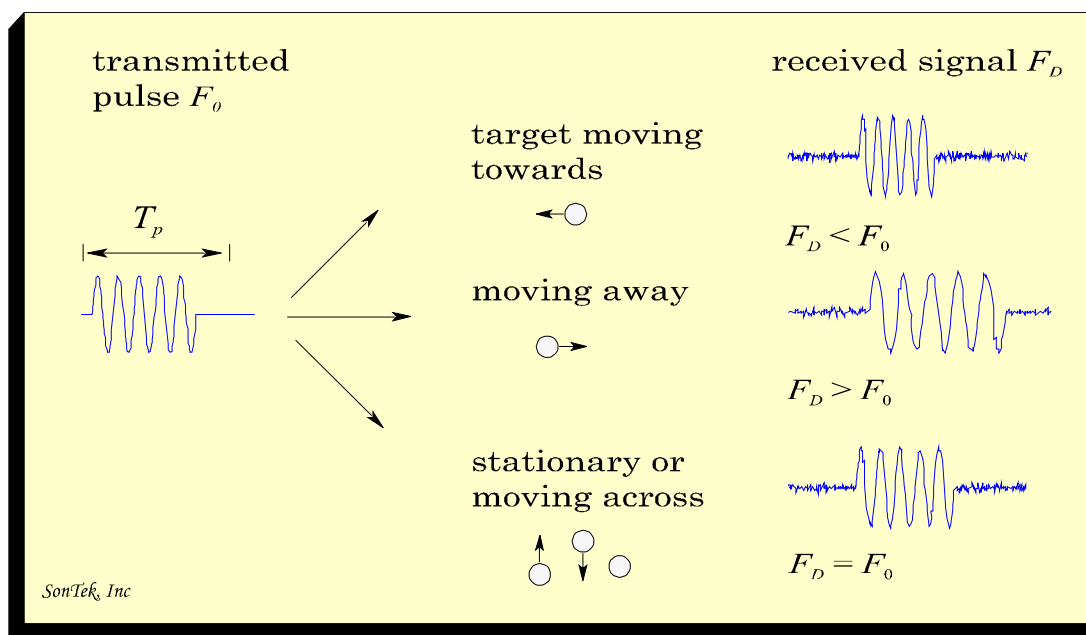
Figure 1 – Doppler Shift for Reflected Sound

Figure 1 shows the basic operation of a Doppler current meter. The change in frequency is calculated by the equation below.

$$F_{doppler} = -2F_{source} \ \frac{V}{C}$$

where

$F_{doppler}$ = Change in received frequency (Doppler shift)
F_{source} = Frequency of transmitted sound
V = Relative velocity of particles
C = Speed of sound

The velocity (**V**) represents the relative speed between the source and scatterers.

- If the distance between the two is decreasing, frequency increases.
- If the distance is increasing, frequency decreases.
- Motion perpendicular to the line connecting the two does not introduce a Doppler shift.

2.1. Monostatic Current Meters
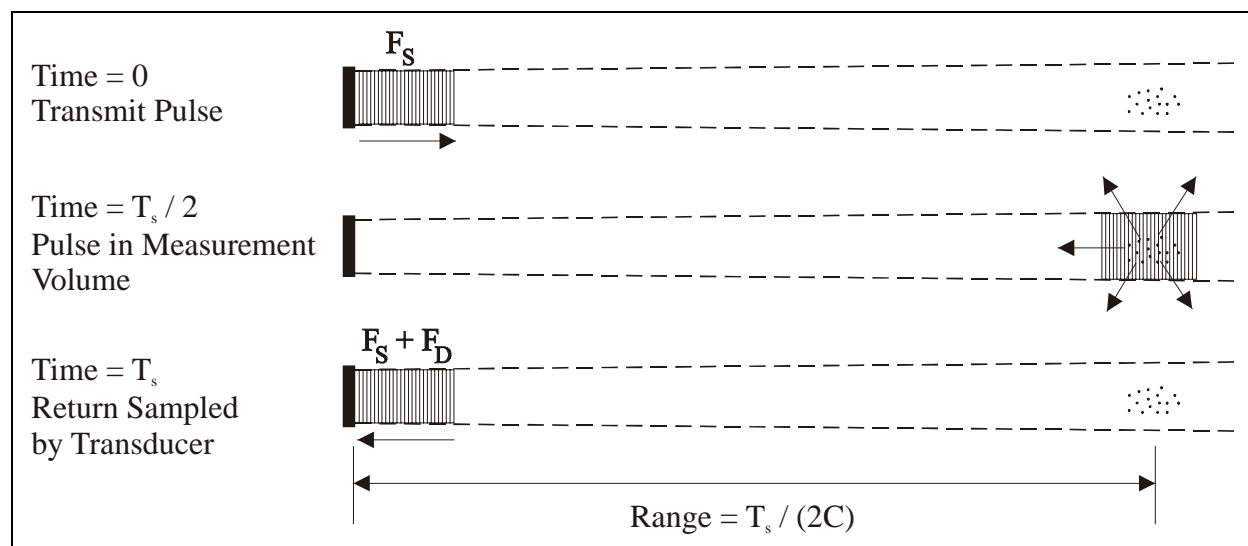
Figure 2 – Monostatic Current Meter

Figure 2 shows the basic operation of a monostatic Doppler current meter such as the ADP.

- Monostatic means the same transducer is used as transmitter and receiver.
- The transducer is designed to generate a narrow beam of sound.
- The transducer generates a short pulse of sound at a known frequency.
- As the sound travels through the water, it is reflected in all directions by particulate matter (sediment, small organisms, bubbles).
- Some portion of the reflected energy travels back along the transducer axis. It is received by the ADP, which measures the change in frequency of the received signal.
- The Doppler shift measured by a single transducer reflects the velocity of the water along the axis of its acoustic beam.

The measurement location is a function of the time at which the return signal is sampled.

- The time since the pulse was transmitted determines how far the pulse has traveled, and specifies the location of the particles that are the source of the reflected signal.
- By measuring the return signal at different times, the ADP measures the water velocity at different distances from the transducer.
- The profile of water velocity is divided into range cells, where each cell represents the average of the return signal for a given period. For example, a 1-m range cell corresponds to an averaging time during which the range to the measurement volume moves one meter.

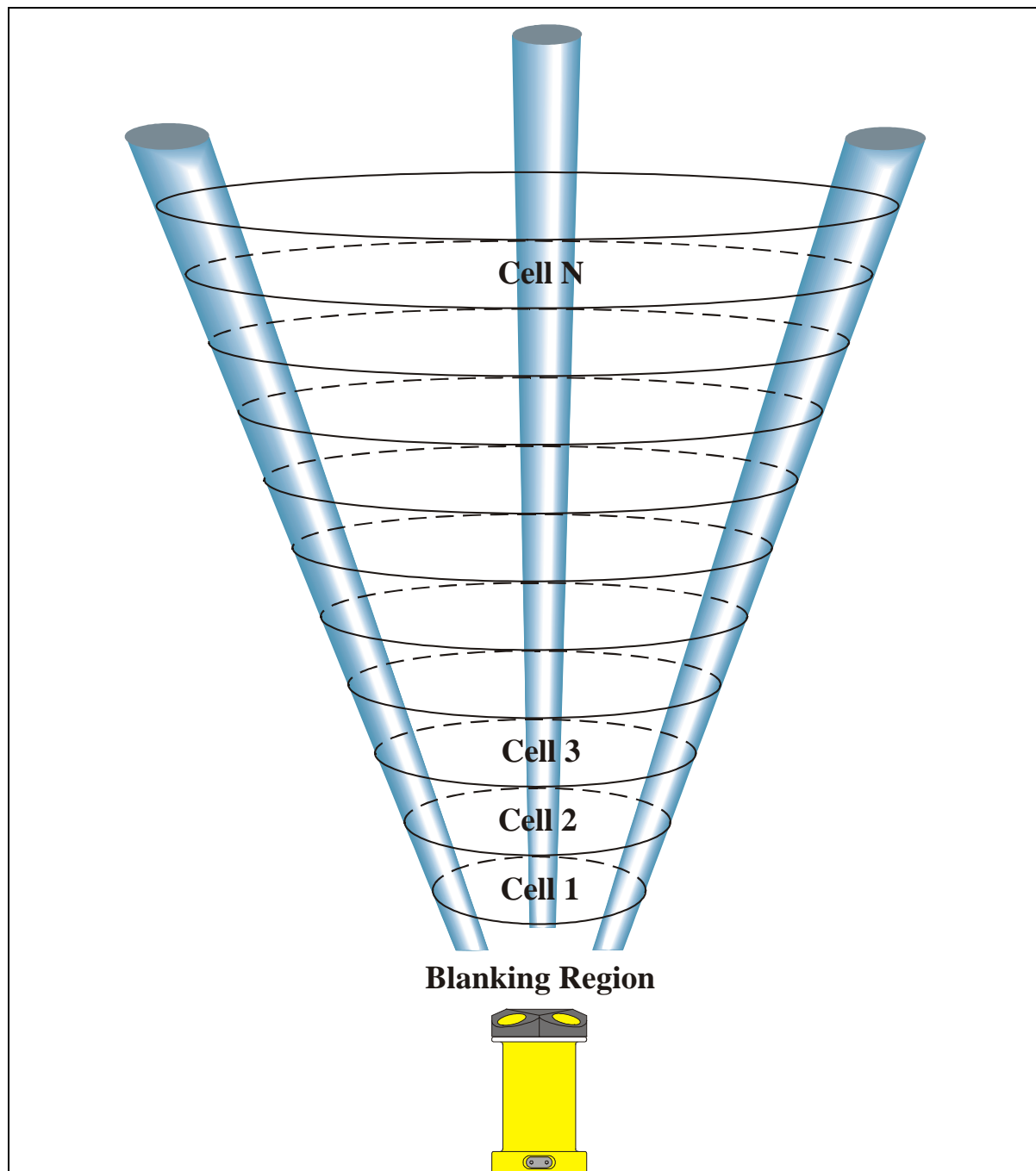# 3. Current Profiling and 3D Velocity Measurements

Figure 3 – ADP Beam Geometry and Current Profiling

Figure 3 shows the operation of the ADP for 3D (i.e., 3-axis) current profiling.

- While shown looking up, the ADP can be used for up, down, or side-looking operation.
- The velocity measured by one ADP transducer is the projection of the 3D velocity onto the axis of the acoustic beam.
- The standard ADP uses three beams oriented 25° off the vertical axis, equally spaced at 120° relative azimuth angles.
- The ADP combines the three along-beam velocities and uses the relative orientation of the transducers to calculate the 3D water velocity.
- Modified beam configurations (e.g., 2-beam, 4-beam) are available for special applications.

The ADP measures the 3D current profile as follows.

- Each transducer generates a short pulse of sound and measures the Doppler shift (velocity) versus time.
- Velocities measured by each beam are called beam velocity data, and are the projection of the 3D velocity onto the axis of the acoustic beam.
- The three beam velocities are combined at each range cell to calculate the 3D velocity in that depth layer. Velocity data is in a Cartesian (XYZ) coordinate system relative to the ADP.
- For many applications, the ADP includes an internal compass/tilt sensor to measures the orientation of the ADP. This allows the ADP to rotate velocity data from the XYZ coordinate system to an Earth (East-North-Up or ENU) coordinate system independent of ADP orientation.
- The ADP samples (or "pings") as rapidly as possible over a user-specified averaging time and reports the mean 3D current profile. The mean profile includes velocity and a variety of associated data, as described in Section 6.

When analyzing ADP data, it is important to understand the inherent spatial averaging.

- To calculate the 3D velocity for a given layer, the ADP uses data from each of the three acoustic beams at the same range.
- The ADP assumes the flow field is uniform across the area covered by the three beams. That is, the water current across each beam is moving at the same speed in the same direction.
- For the standard configuration, the diameter of the area covered by these beams is 0.93 times the distance from the ADP. For example, if deployed on the bottom in 10 m of water, the velocity measurements near the surface are averaged over an area with a diameter of about 9 m.
- Because of the spatial averaging, current profilers are designed to make velocity measurements in environments where there are no strong horizontal flow gradients, and vertical variations are of primary interest.

4. Profiling Range and Spatial Resolution

The ADP profile is divided into different regions, as shown in Figure 3 and Figure 4.

- In front of the transducers is a small region where measurements cannot be made, called the blanking region. This allows the transducers to recover electronically from the transmit pulse and prepare to receive the return signal.
- The remainder of the profile is divided into range cells. Velocity data is averaged according to the user-specified range cell size.

The profiling range and spatial resolution (range cell size) of an ADP is primarily a function of the acoustic frequency.

- Low frequencies provide longer profiling ranges.
- Higher frequencies give shorter profiling ranges with better spatial resolution (reduced range cell size).
- The maximum profiling range is also a function of the amount of acoustic scattering material in the water (see Section 6.3).
- ADPs are available in five frequencies for operation in a wide range of water depths.
- Within the physical limitations of the system, the profiling range and resolution of the ADP are user-specified parameters.

The table below shows the profiling range, resolution, and blanking for various ADP frequencies.

- Maximum profiling range is a range of values to account for variations in the operating environment (different amounts of scattering material in the water).
- Typical resolution shows a range of cell sizes commonly used.
- The blanking distance is the region immediately in front of the transducer where no measurements can be made while the transducers recover from the transmit pulse.
- Minimum depth indicates the shortest profiling range for operation.

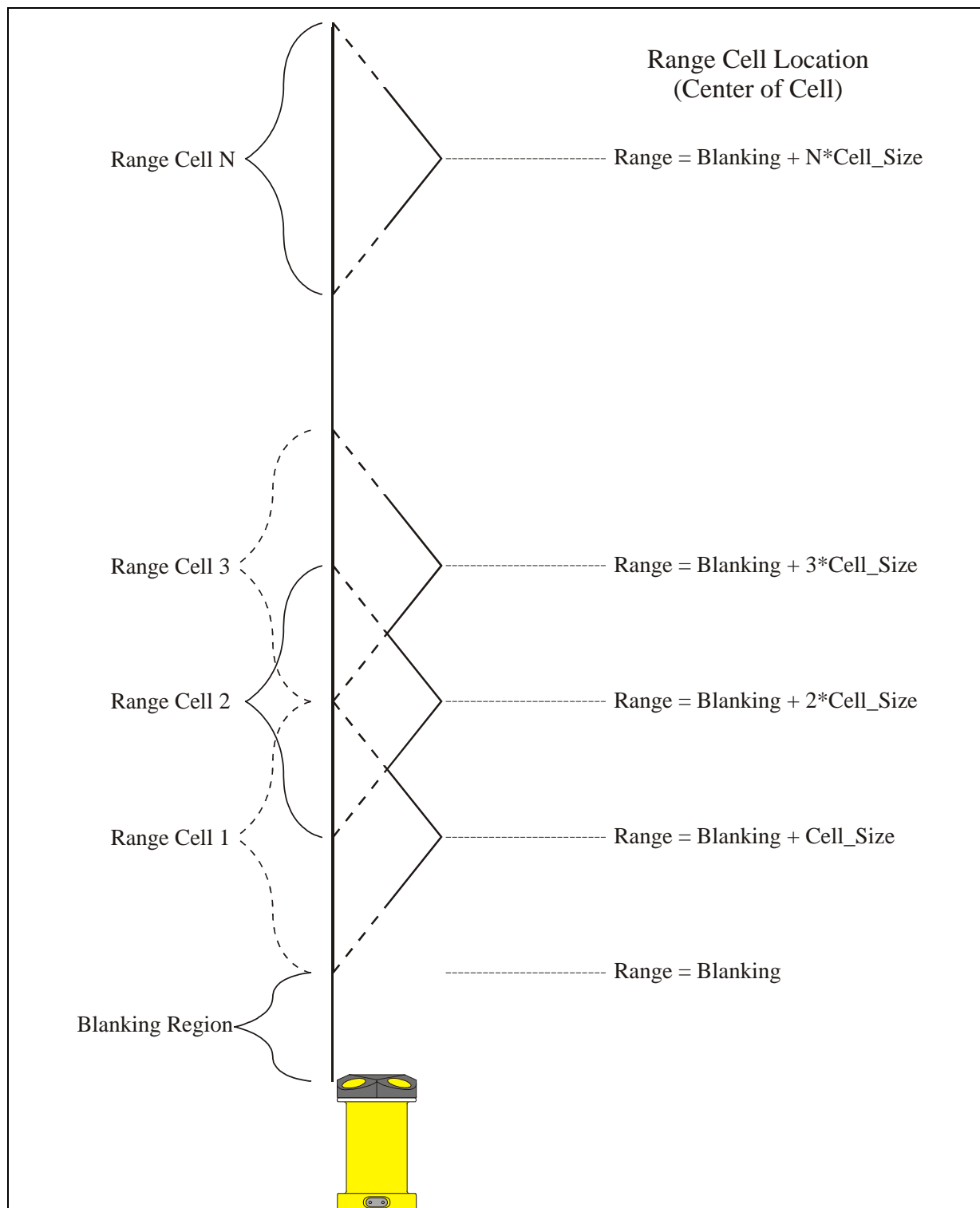| ADP Frequency	Maximum Profiling Range	Typical Resolution	Blanking	Minimum Depth
3000 kHz	3-6 m	0.15 - 0.5 m	0.2 m	0.5 m
1500 kHz	15-25 m	0.25 - 1.0 m	0.4 m	0.9 m
1000 kHz	25-40 m	0.4 - 2.0 m	0.5 m	1.3 m
500 kHz	70-120 m	1.0 - 5.0 m	1.0 m	3.0 m
250 kHz	120-180 m	1.0 - 10 m	1.5 m	3.5 m

5. Range Cell Location and Definition

Figure 4 – ADP Range Cell Location

Figure 4 shows the location of range cells within an ADP profile. The location is different than might be expected because of the true spatial definition of an ADP range cell.

- For most applications, range cells can be considered distinct measurements with the dimension set by the user-specified cell size.
- Only specialized applications need to account for the true range cell definition.
- The true spatial definition of a range cell is determined by the convolution of the acoustic pulse length and the receive window over which the return signal is averaged. The ADP uses the same value for pulse length and receive window. This results in a triangular weighting function where the width of the triangle (the true spatial extent of the range cell) is twice the user-specified range cell size.

We are not including a detailed explanation of the range cell definition in this document; additional information is available on request. The most important conclusions are below.

- The location of the center of each range cell is as shown in Figure 4.
- The true spatial definition of each range cell has a triangular weighting function, with the total width of the triangle twice the user-specified range cell size.
- Adjacent cells overlap, such that the centers of adjacent cells are separated by the user-specified cell size.
- The triangular weighting function is a result of the physical length of the acoustic pulse, and does not indicate weighting within the ADP Doppler processing.
- Each ADP range cell is calculated completely independently. No filtering among adjacent range cells nor assumptions about flow patterns are used.
- While each cell is calculated independently, adjacent cells have 25% overlapping spatial information.

6. ADP Data

The ADP records the following data with each profile.

- Date and time from the ADP's internal clock
- Three velocity values for each range cell, one for each 3D component (see Section 6.2)
- Three signal strength values for each range cell, one for each transducer (see Section 6.3)
- Three standard error values for each range cell, one for each velocity component (see Section 6.4)
- Temperature sensor data
- Compass/tilt sensor data, if installed
- Bottom-track data, if enabled (see Section 7.1)
- GPS data, if enabled (see Section 7.1)
- Pressure sensor data, if installed (see Section 7.6.1)
- Wave spectra data, if installed (see Section 7.6.1)
- SeaBird MicroCat sensor data, if installed (see Section 7.6.2)
- External analog sensor data, if installed (see Section 7.6.3)

6.1. Sampling

The following describes the ADP sampling strategy.

- An individual measurement of the 3D velocity profile is called a ping.
- The ADP pings as rapidly as possible (4 to 20 times per second depending upon frequency; see Section 6.4).
- Pings are averaged over the user-specified averaging interval to produce a mean 3D velocity profile.
- Increasing the averaging interval decreases the uncertainty in each mean profile. See Section 6.4 for a discussion of measurement noise in ADP velocity data.

6.2. Velocity

The ADP Doppler processing provides several important performance advantages.

- It can measure 3D water velocities from 0.1 to 1000 cm/s.
- The ADP calibration will never change; that is, no re-calibration is required.
- For most applications, velocity data can be used without any postprocessing corrections.
- Velocity data is output in either (1) Cartesian coordinates (XYZ) that are relative to probe orientation, or (2) Earth coordinates (East-North-Up or ENU) for systems with a compass/tilt sensor.
- The only time postprocessing corrections are required is when sound speed has been incorrectly specified (see Section 7.4).

Factors that affect velocity data include accuracy and noise.

6.2.1. Accuracy

ADP accuracy is specified as follows.

- Accuracy refers to bias in velocity measurements after removing noise (see Section 6.4).
- Two factors influence the accuracy of the ADP: sound speed and beam geometry.
- The effect of sound speed on velocity measurements is discussed in Section 7.4. Sound speed errors are typically negligible (less than 0.1%); larger errors (which are uncommon) can be corrected in postprocessing.
- Beam geometry is fixed during manufacturing; no re-calibration is required.
- Velocity accuracy is specified to ±1.0% of the measured velocity.
- There is no potential for zero offset in velocity measurements, giving excellent low-flow performance.

6.2.2. Short-Term Uncertainty (Noise)

All Doppler velocity systems have inherent measurement noise.

- The noise is a result of the physical process by which the sound waves are scattered from particles in the water, and is referred to as Doppler noise.
- Doppler noise is random and can be assumed to follow a Gaussian distribution.
- Averaging multiple data points converges to the true value without introducing bias.
- Noise decreases with the square root of the averaging interval. (i.e., data using a 4-minute averaging interval has half the noise of a 1-minute averaging interval [$0.5 = \sqrt{(1/4)}$]).

Section 6.4 describes how to predict Doppler noise in ADP velocity measurements.

6.3. Signal Strength

Signal strength is a measure of the magnitude of the acoustic reflection from the water.

- Signal strength decreases with range due to geometric spreading and absorption.
- Signal strength is accessed as raw signal amplitude (using internal units called counts, where one count equals 0.43 dB) or as a signal-to-noise ratio (SNR in dB).
- The maximum profiling range is determined by the range where signal strength approaches the noise level (see Section 6.2.2), or by the range at which the pulse hits a boundary (surface or bottom).
- The maximum profiling range of the ADP (without a boundary present) is a function of the acoustic frequency and the strength of the scattering return from the water.

Signal strength is a function of the amount and type of particulate matter in the water.

- Signal strength can be used as a measure of sediment concentration.
- While ADP signal strength data cannot be immediately converted to sediment concentration, it provides an excellent qualitative picture of sediment fluctuations and, with proper calibration, can be used to estimate sediment concentration. For more information about this application, contact SonTek.

The primary use for signal strength data is to determine the range over which the instrument can accurately measure velocity. There are several distinctive features in a profile of signal strength.

- At the transducer, signal strength typically starts at 120-180 counts (SNR 40-60 dB).
- Signal strength follows a logarithmic decay as distance from the transducer increases.
- If a boundary (surface or bottom) is within range, a spike will be seen corresponding to the reflection of the acoustic pulse. The shape and height of the spike varies with distance from the transducer and the nature of the boundary.

Factors limiting the profiling range of the ADP include return signal decay and boundary interference.

- At some range, signal strength reaches the noise level and the ADP cannot measure velocity. This range is a function of acoustic frequency and the conditions in the water.
- Generally, the end of the profile is the point where the SNR drops below 3 dB.
- If a boundary (surface or bottom) is within range, the end of the profile is determined by where the ADP sees the reflection from the boundary.
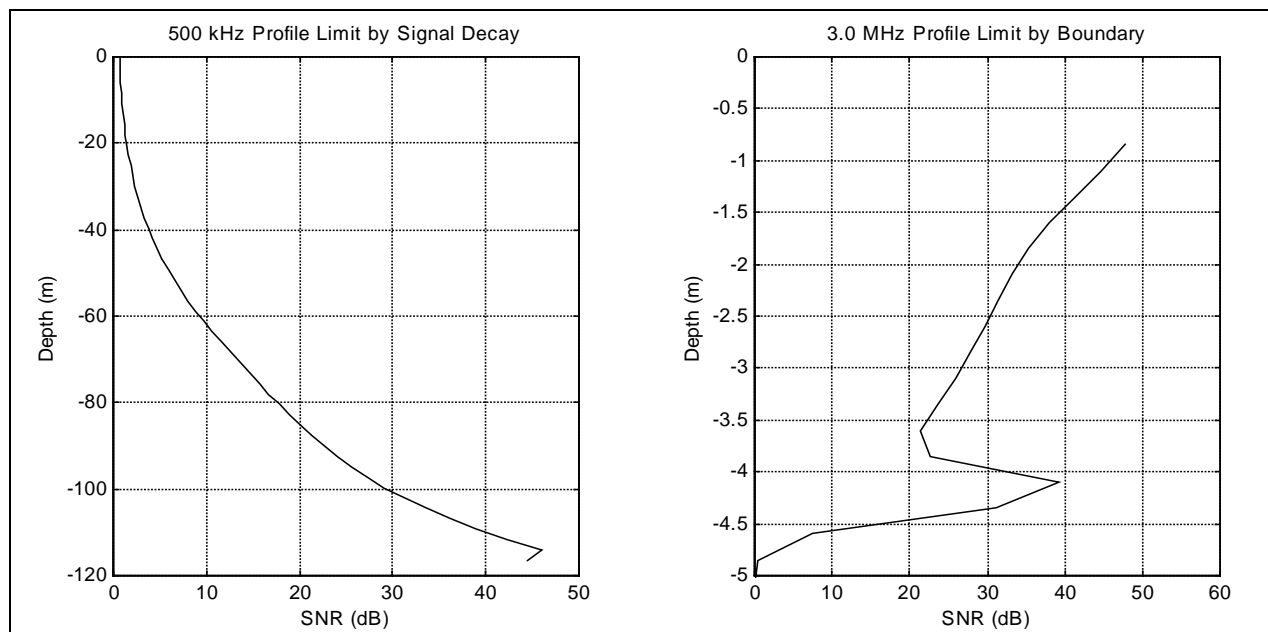
Figure 5 – ADP Example Signal Strength Profiles

Figure 5 shows examples of how profiling range is determined.

- The plot on the left shows the SNR (for one beam) from a 500-kHz ADP looking up from a depth of 120 m. The maximum profiling range is the point where SNR drops below 3 dB (at a depth of about 20 m). Data beyond this point cannot be used.
- The plot on the right shows the SNR from a 3000-kHz ADP looking down in about 4 m of water. The effective profiling range is determined where the ADP sees the reflection from the bottom. For this example, the peak bottom reflection occurs at a depth of about 4.1 m; the last good measurement is the cell located at about 3.6 m.

Signal strength varies considerably with the operating conditions of the ADP.

- The features shown here should be distinguishable, but some variation should be expected.
- The signals measured by the ADP are very small – ambient electronic noise and obstructions in the water can have a significant affect. Deployments in areas with large structures (piers, docks, etc.) should be carefully planned to avoid interference.
- The typical maximum profiling range for various ADP frequencies was shown in Section 4.

6.4.   Standard Error

The ADP provides a standard error of velocity value that is a direct measure of the quality of velocity data.

- The ADP reports one standard error value for each velocity component for each range cell (in the user-specified coordinate system, XYZ or ENU).
- Standard error can be directly interpreted as an estimate of the accuracy of velocity data.
- Standard error includes instrument-generated uncertainty (Doppler noise), real variations in water velocity, and motion of the ADP installation (e.g., if mounted on a buoy or mooring line, or if used from a moving boat).

Standard error is calculated as follows.

- A number of pings are averaged during the user-specified averaging interval.
- A mean velocity value is reported.
- The standard deviation of velocity for all pings is divided by the square root of the number of pings to compute standard error.
- Predicted Doppler noise (described below) reflects only instrument-generated uncertainty (it does not account for real variations in water velocity or motion of the ADP installation).

The profile of standard error should be essentially constant where SNR is greater than 3 dB and no boundary is present.

- As SNR decreases below 3 dB, standard error increases rapidly; this increase can be used to determine the end of the effective profiling range in situations without a boundary.
- It is difficult to predict the standard error at the boundary, as these values will vary depending upon the nature of the reflected signal.

Doppler noise is a function of the ADP system configuration, acoustic frequency, range cell size, and the number of samples (pings) used to calculate the mean velocity profile.

For the standard 3D ADP, Doppler noise is estimated as

$$\sigma = \frac{235}{F \Delta z \sqrt{N}}$$

For a 2D side-looking ADP (see Section 7.5), Doppler noise is estimated as:

$$\sigma = \frac{205}{F \Delta z \sqrt{N}}$$

where

σ = Doppler noise of horizontal velocity measurement (m/s)
F = Acoustic frequency (kHz)
Δz = Range cell size (m)
N = Number of samples

To calculate the Doppler noise, the ping rate must be known.

- The number of samples is simply the averaging interval (in seconds) multiplied by the ping rate (in samples per second).

Frequency	Profiling Range (m)	3D ADP Ping Rate	2D Side-Looking ADP Ping Rate
3000 kHz	3-6	20	30
1500 kHz	15-25	9	13
1000 kHz	25-40	6 / 12 (see below)	8
500 kHz	70-120	2.0 / 4.5 (see below)	3.0
250 kHz	120-180	1.2-2.0 / 2.9-4.0 (see below)	1.7-2.7 (see below)

Two different ping rates are shown for the 1000, 500, and 250-kHz 3D ADP.

- The lower ping rate is for standard systems intended for stationary deployment (i.e., bottom-mounted).
- The higher ping rate is for systems used from a moving boat. These systems are modified to increase the ping rate to allow higher resolution.

The ping rate of the 250-kHz ADP varies with the user-specified measurement range (based on range cell size and the number of cells). Ping rate for the 250-kHz ADP can be calculated for a particular measurement range (in meters) using the formulas below.

- For standard 3D, 250-kHz ADPs used in stationary deployments:

$$PingRate = \frac{250}{25 + MeasurementRange}$$

- For 3D, 250-kHz ADPs used from a moving boat:

$$PingRate = \frac{750}{75 + MeasurementRange}$$

- For 2D, 250-kHz side-looking ADPs (used only in stationary deployments):

$$PingRate = \frac{375}{37 + MeasurementRange}$$

The following tables show predicted Doppler noise for various ADP frequencies at two range cell sizes. Tables are provided for both the standard 3D ADP and for the 2D side-looking ADP (see Section 7.5). The tables list Doppler noise for a single ping, and the time required to reach a noise level of ±1 cm/s.

The predicted values reflect only instrument-generated uncertainty (Doppler noise).

- Real variations in water velocity will increase the measured standard error values.
- Any motion of the ADP (e.g., when installed on a buoy or mooring line, or when used from a moving vessel) will increase the standard error of velocity measured by the ADP.
- In some applications, uncertainty due to motion of the ADP can dominate the standard error of velocity measurements.

For standard 3D ADP systems:

Frequency	Range Cell (m)	Single Ping Doppler Noise	Averaging Time for $\sigma <= \pm 1$ cm/s
3000 kHz	0.25	31 cm/s	50 s
	0.50	16 cm/s	15 s
1500 kHz	0.50	31 cm/s	110 s
	1.0	16 cm/s	30 s
1000 kHz	1.0	24 cm/s	100 / 50 s *
	2.0	12 cm/s	25 / 15 s *
500 kHz	2.0	24 cm/s	280 / 130 s *
	4.0	12 cm/s	80 / 35 s *
250 kHz	4.0	24 cm/s	280-460 / 140-190 s *
	8.0	12 cm/s	70-120 / 35-50 s *

* See discussion about 1000, 500, and 250-kHz ping rates above.

For 2D side-looking ADPs (see Section 7.5):

Frequency	Range Cell (m)	Single Ping Doppler Noise	Averaging Time for $\sigma <= \pm 1$ cm/s
3000 kHz	0.25	27 cm/s	30 s
	0.50	14 cm/s	10 s
1500 kHz	0.50	27 cm/s	60 s
	1.0	14 cm/s	15 s
1000 kHz	1.0	21 cm/s	60 s
	2.0	10 cm/s	15 s
500 kHz	2.0	21 cm/s	150 s
	4.0	10 cm/s	40 s
250 kHz	4.0	21 cm/s	160-250 s *
	8.0	10 cm/s	40-70 s *

* See discussion about 250-kHz ping rates above.

7. Special Considerations

7.1.   Moving-Boat Operation

A powerful application of the ADP is current measurements from a moving boat.

- The ADP is mounted looking down from a boat or towed platform.
- The ADP measures the profile of water velocity relative to the boat.
- The ADP uses bottom-tracking to measure the speed of the boat relative to the bottom.
- The boat speed (from bottom-track data) is subtracted from the measured water velocity to give the absolute current profile independent of boat motion.

ADP moving-boat applications offer the ability to make measurements that cannot be made with any other type of current meter.

- Measuring the absolute current profile from a moving boat allows the ADP to perform current surveys over large areas in a short amount of time.
- Integrated GPS position gives a map of the water currents over the area of interest.
- The ADP simultaneously measures bottom depth, adding bathymetry to the data set and providing a built-in means to determine the end of the ADP velocity profile.
- The robustness and ease of use of the ADP lets you collect data with a minimum of preparation, reducing costs and ensuring the best quality data possible.

ADP moving-boat applications are described in detail in a separate technical note; please contact SonTek for details.

7.2.   River Discharge Measurements

A subset of ADP moving boat applications is river discharge measurement.

- The ADP is mounted from a small boat or towed platform.
- The ADP measures the absolute currents using bottom-track data to account for vessel motion.
- The boat or platform is moved slowly from one side of a river to the other side.
- The ADP combines all velocity and bottom-track data to compute the total river discharge. The ADP simultaneously reports detailed bathymetry information and the distribution of currents across the river.

ADP measurements of river discharge offer the following advantages.

- Rapid, accurate measurement of river discharge.
- Simple, robust operation with minimal training required.
- A complete, integrated package including a towed catamaran (the RiverCat) is available.

ADP river discharge measurements are discussed in detail in a separate technical note; please contact SonTek for details.

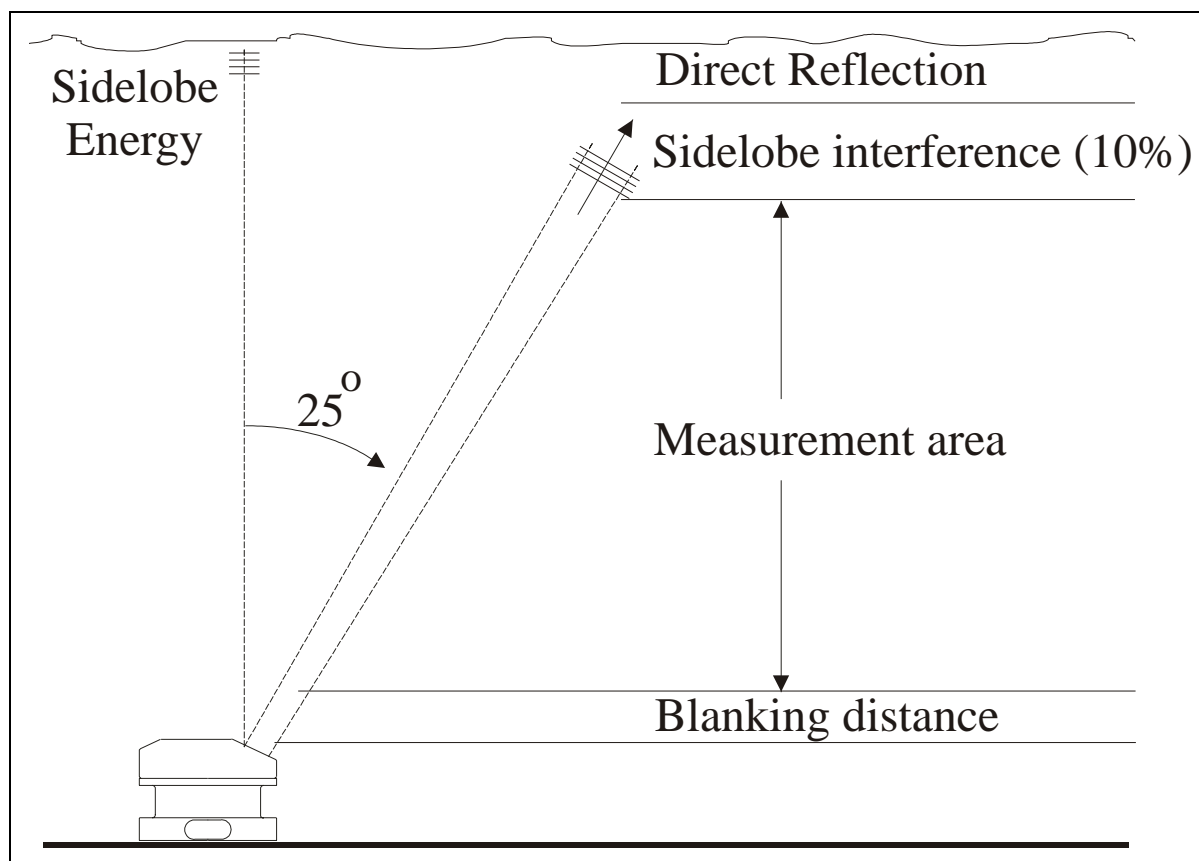### *7.3. Near-Boundary Data Collection*

Figure 6 – ADP Near-Boundary Operation

Figure 6 shows an upward looking ADP near a boundary (the surface). For near-boundary operation, the profile is divided into several areas.

- Following the blanking region, the ADP makes velocity measurements in range cell sizes selected by the user.
- As the profile approaches the boundary, there are two potential sources of interference: direct reflection of the pulse from the boundary, and the reflection of side-lobe energy taking a direct (shorter) path to the boundary.
- The same considerations apply to a down-looking system near the bottom.

ADP transducers are designed to concentrate most of the acoustic energy in a narrow beam; however, some energy is transmitted in all directions.

- As shown in Figure 6, some energy takes a direct (shorter) path to the boundary and reflects off the boundary while the main portion of the beam is still in clear water.
- This is called side-lobe energy and the reflections from a boundary are called side-lobe interference.
- Although side-lobe energy levels are much lower than the main beam, the reflection from the boundary is much stronger than the reflection from particles in the water. Thus, side-lobe reflections can potentially bias velocity measurements.
- Side-lobe interference may affect the last 10% of the velocity profile (for the standard ADP with a 25° beam-mounting angle).
- The extent to which the side-lobe reflections affect the velocity measurements is a function of the boundary conditions, the scattering return strength from the water, and the acoustic properties of the transducers.

SonTek has made considerable advances in designing transducers with reduced side-lobe levels.

- Reduced side-lobe energy levels decrease the possibility of side-lobe interference.
- Our experience has shown that in most conditions, SonTek ADPs do not see any identifiable evidence of side-lobe interference and do not lose the last 10% of the velocity profile.
- There is always a potential for side-lobe interference, and any near-boundary data should be analyzed carefully.

As previously described, Figure 5 shows a typical signal-strength profile with boundary reflection.

- The peak reflection occurs in the cell whose center is closest to the bottom.
- The cell immediately before the peak usually sees some portion of this reflection. Cells before this should be looked at carefully for signs of interference.
- In areas with significant wave action, the lowest surface height can potentially extend several cells below the peak.
- The peak cell, and the cell immediately before the peak, should always be discarded. The next few cells should be examined closely for signs of increased signal strength (caused by reflections from the boundary) or for unusual features in the velocity and standard error data.

7.4. Sound Speed

The ADP uses sound speed to compute velocity from the measured Doppler shift. This section discusses how to correct ADP velocity data for errors in the sound speed value used during data collection. Sound speed errors are typically small; postprocessing corrections are rarely required.

The speed of sound in water is primarily a function of temperature and salinity.

- The ADP includes a temperature sensor (±0.1° C) for automatic sound speed corrections.
- A user-input value of salinity is used in the sound speed calculations.
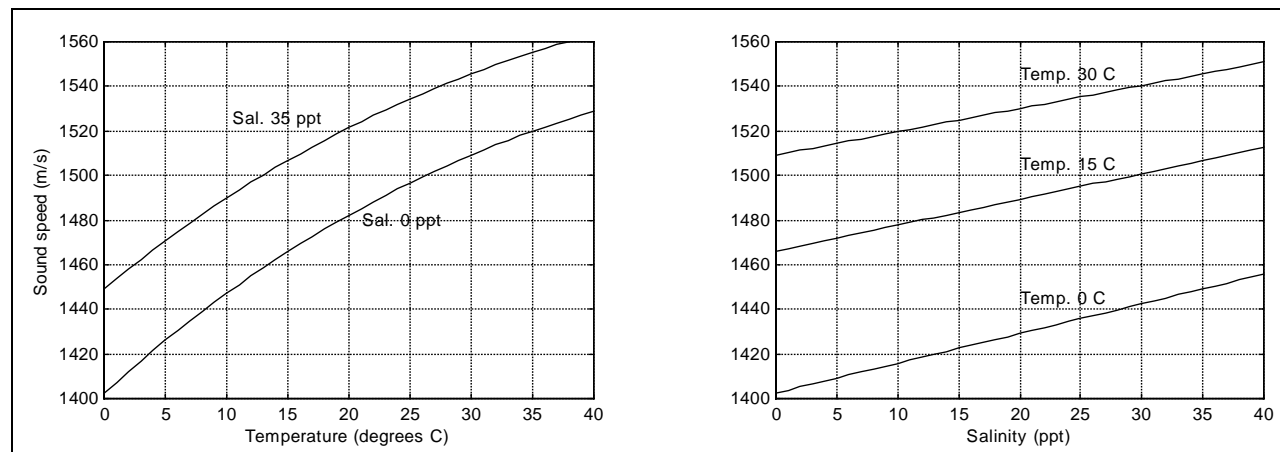
Figure 7 – Sound Speed as a Function of Temperature and Salinity

Figure 7 shows sound speed as a function of temperature at different salinity levels (left panel) and salinity at different temperature levels (right panel). As a general rule:

- A temperature change of 5° C results in a sound speed change of 1%.
- A salinity change of 12 ppt results in a change in sound speed of 1%.
- The full range of typical temperature and salinity levels (-2 to 40°C and 0 to 40 ppt) gives a sound speed range of 1400 to 1570 m/s (total change of 11%).

For the ADP, output velocities (in any coordinate system - Beam, XYZ, or ENU) scale directly with sound speed; a 1% error in the sound speed results in a 1% error in velocity measurements. The following formula is used for postprocessing corrections, and can be directly applied to the output velocities of the ADP:

$V_{true} = V_{orig} (C_{true} / C_{orig})$

where

V_{true} = Corrected velocity measurements (in any coordinate system)
V_{orig} = Uncorrected velocity measurements (in any coordinate system)
C_{true} = True speed of sound
C_{orig} = Speed of sound used in original calculations

Changes in sound speed also affect the physical location of ADP range cells, although these errors are generally small. To correct the position of ADP range cells, use the following:

$Z_{true} = Z_{orig} (C_{true} / C_{orig})$

where

Z_{true} = Corrected range cell location (range from transducer)
Z_{orig} = Uncorrected range cell location (range from transducer)

7.4.1. Stratified Flow

A common question is how a stratified water column (changes in sound speed with depth) affects ADP operation. Figure 8 illustrates this question.
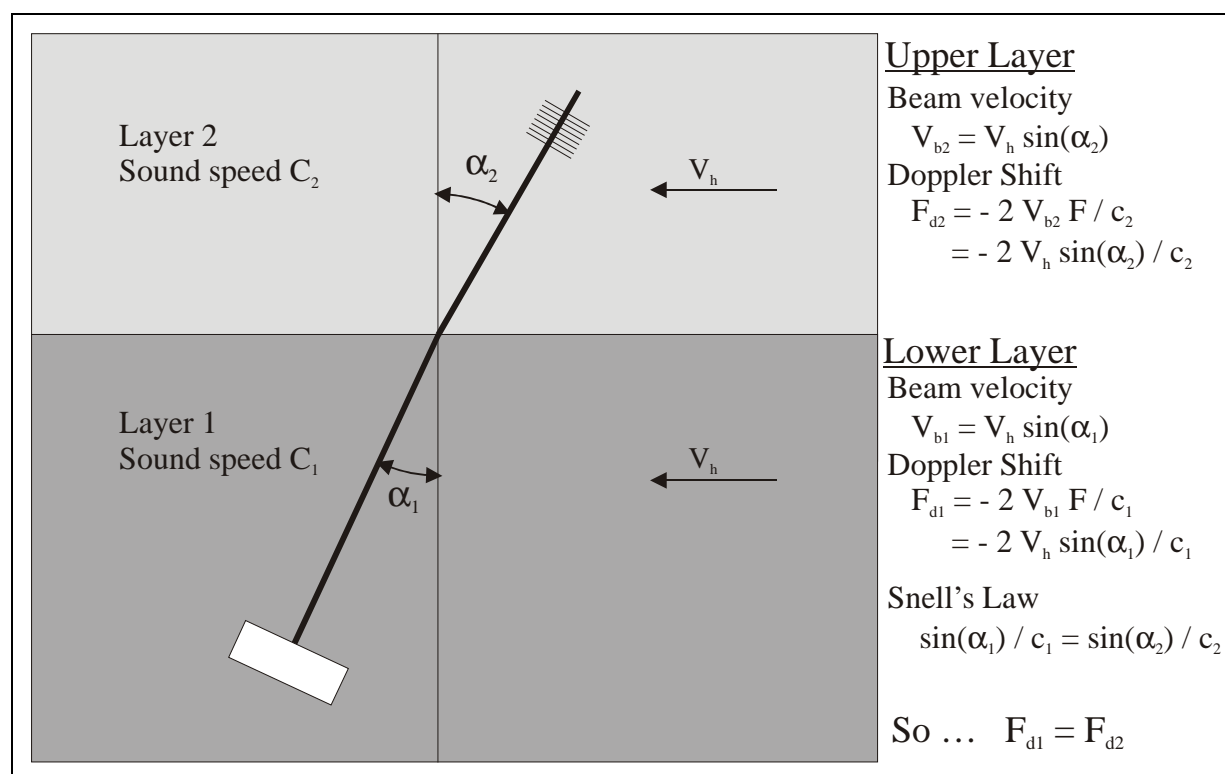
Figure 8 – ADP Operation in Stratified Flow

The answer is that variations in sound speed through the water column have no effect on ADP horizontal velocity measurements.

- The ADP only needs to know the sound speed at the transducers.
- The refraction of the acoustic beam at the interface of two layers has a geometric effect equal and opposite to the effect of changes in sound speed.
- Figure 8 shows the measured Doppler shift for an identical horizontal velocity in two layers.

7.5. Horizontal Current Profiling

The standard ADP uses three beams for vertical current profiling, looking up or down. There are several applications where a current profiler can be used looking horizontally. These applications require a two-beam ADP that measures the 2D velocity profile in a horizontal layer.
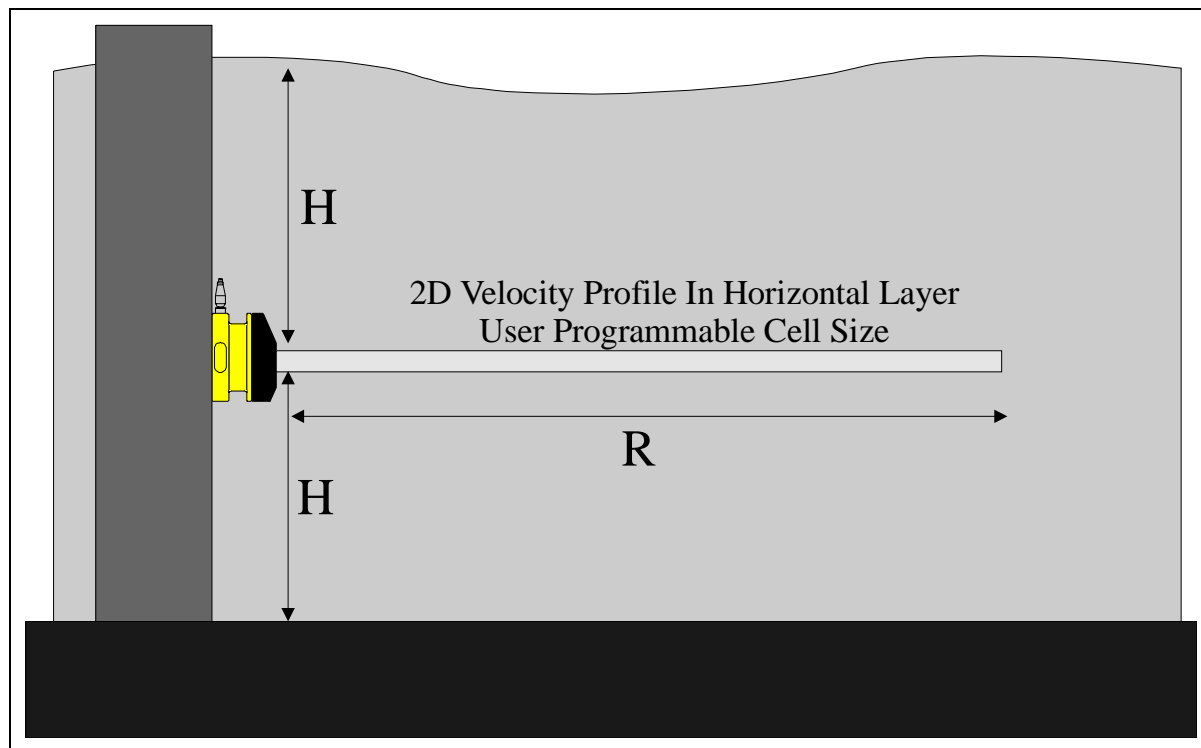
Figure 9 – ADP Horizontal Current Profiling

A 2D ADP is typically mounted from some type of underwater structure (e.g., bridge piling).

- The two beams are mounted in a plane parallel to the surface and bottom.
- This instrument operates exactly like a standard ADP except that the two beams measure the profile of water velocity with horizontal range, and return the two horizontal velocity components.

The primary limitation of horizontal profilers is the maximum range relative to depth.

- This is expressed as the aspect ratio between profiling range and the distance to the nearest boundary (R / H as pictured in Figure 9).
- While ADP transducers generate very narrow beams, these beams will spread, and after some distance, will begin to see interference from the boundaries (surface, bottom).
- Experience has shown that the ADP can operate without interference to an aspect ratio of about 10 in almost all conditions, and in some situations to aspect ratios of 20 or higher. For example, a 500-kHz 2D ADP installed at mid-water depth in 5 m of water has reliably worked to ranges over 60 meters (an aspect ratio of about 24).

7.6. *External Sensor Integration*

The ADP has been designed to allow integration of other sensors with all data stored in a single file. Three primary sensor types are available (in addition to the temperature sensor included standard with all systems).

- Pressure (strain gage or RPT)
- CTD (SeaBird MicroCat)
- Analog sensors

7.6.1. *Pressure Sensor – Surface Level and Wave Spectra*

A pressure sensor provides an integrated measurement of deployment depth / surface level, and a simple means for determining the end of the profile for up-looking ADP installations. Two types of pressure sensors can be added to the ADP.

- Strain gage pressure sensor: ±0.1% of full scale, 10 to 600-m depth ranges.
- Resonant pressure transducer (RPT) sensor: ±0.01% of full scale, 20-m depth range.

The ADP pressure sensor can also include special software to collect and record estimates of wave frequency spectra.

- Spectra are estimated from the 1-Hz pressure time-series over the averaging interval.
- The estimation uses standard methods appropriate to simple linear theory – segmentation of the data in 256-point segments with at least 128-point overlap between consecutive segments; application of Hanning window to each segment with constant energy correction; and correction for sensor/water depth using general first order dispersion relationship for surface waves.
- Wave spectral estimates are presented as an array of coefficients, each giving the mean wave amplitude (square root of the energy) within a period band. Ten bands are used, which correspond to two-second periods ranging over 2 to 20+ seconds.
- Significant wave height and peak wave period are also reported.
- Wave spectral estimates and raw 1-Hz pressure data are recorded with each profile.

For each band, the ADP computes and reports the mean wave amplitude (**A**) for waves within the period range in the band. If $\mathbf{A_i}$ is the amplitude for band *i*, the total wave energy is given by:

$$\text{Total Energy } (\sigma_A{}^2) = \Sigma(\ A_i{}^2\ ) \text{ for i=1 to 10}$$

A generally accepted estimate of the significant wave height can be easily obtained from the amplitudes using:

$$H_{mo} = 4 \times \sqrt{(\text{Total Energy})}$$

7.6.2. SeaBird MicroCat CTD

SeaBird is the recognized leader in high-precision temperature and conductivity measurements.

- SonTek has integrated the MicroCat with the ADP to provide the most accurate velocity, temperature, and conductivity measurements in a single integrated package.
- The SeaBird MicroCat offers temperature accuracy of 0.002°C and conductivity accuracy of 0.0003 S/m.
- The ADP controls MicroCat operation (using a built-in RS232 serial interface) and collects one synchronized CT sample with each velocity sample.
- The data is stored in the same file as the ADP velocity data for easy analysis.

7.6.3. Analog Sensors

The ADP has the ability to sample up to three additional analog voltage inputs from external sensors.

- Each input must be in the range 0-5 VDC.
- The ADP uses a 12-bit analog-to-digital (A/D) converter to sample the input voltages.
- Each voltage is sampled once per second during the user-specified averaging time; mean and standard deviation are recorded with each profile.
- Depending on sensor requirements, the ADP may be able to provide power to the sensor.
- Special wiring and software modifications are required for external analog sensors.
- The data is stored in the same file as the ADP velocity data for easy analysis.

A variety of sensors can be integrated with the ADP.

- Turbidity (OBS)
- Transmissometer
- Fluourometer
- Dissolved oxygen

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Using Frequency Pressure Sensors with SonTek ADPs, Hydras, and Argonauts

This document describes the use of *frequency pressure sensors* with SonTek acoustic Doppler current meters. SonTek supports two types of frequency pressure sensors: (1) the Druck RPT, a silicon resonant transducer (referred to as DRUCK) manufactured by Druck, Inc. and (2) the Paroscientific digiquartz transducer (referred to as PAROSFREQ) manufactured by Paroscientific, Inc.

1. Overview

Typically, SonTek instruments include *analog pressure sensors* (e.g., strain gage) that provide sufficient accuracy and stability (0.1 to 0.25 %) at a moderate cost. These sensors are usually installed within the system head (Figure 1). They are internal to the system and are usually referred to as PRESSURE or PRESSURE SENSOR within our documents and system command interface.

Some applications, however, require better long-term stability (e.g., tide studies, wave interaction with topography, long-term water-level monitoring, etc.). To accommodate these needs, SonTek has integrated *frequency pressure sensors*, which offer an order of magnitude better accuracy and stability (0.01%). The first supported sensor was the Paroscientific digiquartz with a serial interface (PAROS). These sensors, because of their size did not fit inside our systems and were mounted externally (Figure 1). The next supported sensor, the Druck RPT, did fit inside an ADP or ADVOcean head. However, for historical purposes, all *non-strain gage sensors* are usually referred to as EXTERNAL PRESSURE SENSOR within our documents and system command interface.

2. Serial External Pressure Sensors (PAROS)

As mentioned, the first external pressure sensor supported by SonTek was the Paroscientific digiquartz with serial interface (PAROS). The PAROS is connected to a system by a 1 to 2-m cable. The PAROS is available for ADP, PC-ADP, and Hydra systems. The differences, when compared with a strain-gage sensor, are as follows:

- The PAROS is an absolute sensor. It reads 1 dbar in air; a strain gage reports 0 dbars in air.
- Sampling rate is limited to 4 Hz (ADVs and Hydras) due to serial interface limitations.
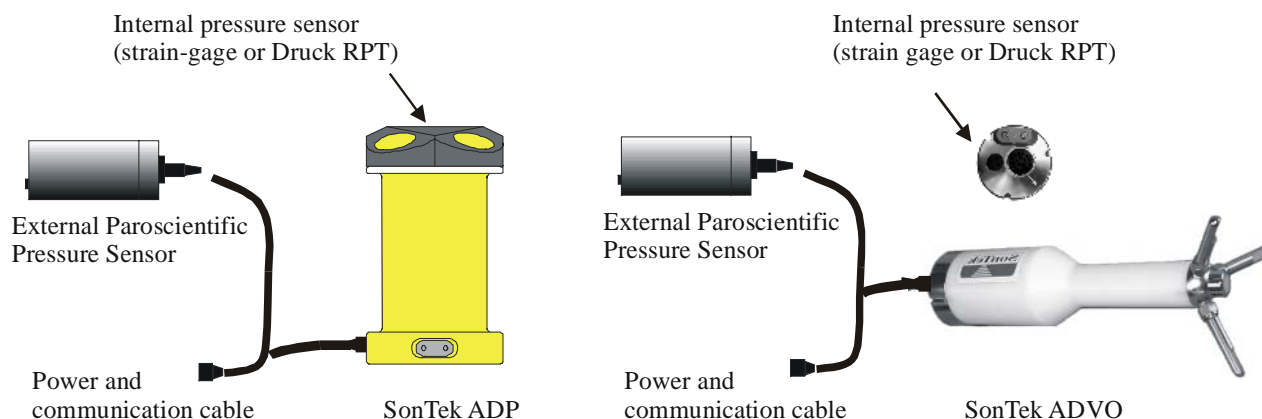

Figure 1: ADP and ADVOcean with external pressure sensors.

3. Frequency External Pressure Sensors

3.1.   The Druck RPT (DRUCK)

Although the PAROS provides the required accuracy, its size and external location cause additional complications when mounting and deploying a system. SonTek, in collaboration with Druck, Inc., now offers the Druck RPT (resonant pressure transducer) sensor. This sensor is very compact and fits inside the same mounting socket as the regular strain gage (Figure 1). The DRUCK sensors are available for ADP, PC-ADP, Argonaut SL/XR, and Hydra systems. The differences, when compared with a strain-gage sensor, are as follows:

- The DRUCK is an absolute sensor. It reads 1 dbar in air; a strain gage reports 0 dbars in air.
- Requires a special interface to sample the frequency signal.
- Sampling rate is limited to 10 Hz (ADVs and Hydras) because of the time required to sample the frequency signal with sufficient precision.
- Requires calibration matrix (specific to each sensor) to be loaded into the processor (system CPU or a user PC) to obtain valid pressure readings.
- Available in 50-psia pressure rating only (equivalent to ≈22 dbar strain gage).

3.1.1. Sensor Calibration Template

Each current meter purchased from SonTek that has the DRUCK sensor installed already has the appropriate calibration coefficients loaded into the processor. If this information is lost, you can use the calibration sheet provided by the pressure sensor vendor to construct your own calibration file. The structure of the DRUCK calibration file, required by SonTek systems, is as follows.

- Pressure Sensor Serial Number
- Oscillator Frequency (in Hz)
- X
- Y
- Low end of temperature range
- Corresponding voltage of the diode
- Diode sensitivity
- K00 K01 K02 K03
- K10 K11 K12 K13
- K20 K21 K22 K23
- K30 K31 K32 K33
- K40 K41 K42 K43
- K50 K51 K52 K53

> Note: The X, Y, and K coefficients can be found on the Druck calibration sheet.

Example – Druck calibration file **1145118.drk**:

```
1145118
12.0000000E+06
+8.8880000E+03
+5.5200000E+02
-10
622
-2.21
+1.6214761E+03   -2.0699499E-02   +5.5220000E-05   -5.6160001E-08
+1.8251241E+00   -5.8612000E-06   +3.6197001E-08   -3.8715001E-10
+3.8615943E-04   -1.5274000E-09   -4.7059999E-12   -1.3233001E-13
+7.0553313E-08   -1.9064000E-12   -4.0058001E-14   +9.0119996E-16
+1.7913088E-11   -1.3525000E-15   +1.7647000E-17   +3.8552999E-19
+3.7756621E-15   +1.9573000E-19   +3.6951001E-20   -3.3300999E-22
```

3.2. The Paroscientific Digiquartz (PAROSFREQ)

User requirements for deeper ratings (compared to DRUCK) and faster response (compared to PAROS) convinced SonTek to offer the Paroscientific digiquartz sensor with frequency output (PAROSFREQ). Functionally, the interface for the PAROSFREQ is identical to the interface for the DRUCK, as both are frequency-based sensors. The PAROSFREQ sensors are available for ADP, PC-ADP, and Hydra systems. The differences, when compared with a strain-gage sensor, are as follows:

- The PAROSFREQ is an absolute sensor. It reads 1 dbar in air; a strain gage reports 0 dbars.
- Requires a special interface to sample the frequency signal.
- Requires a special frequency splitter cable.
- Sampling rate is limited to 10 Hz (ADVs and Hydras) because of the time required to sample the frequency signal with sufficient precision.
- Requires a calibration (specific to each sensor) to be loaded into the processor (system CPU or a user PC) to obtain valid pressure readings.
- Available in 50-psia (≈22 dbar strain gage) and 100-psia (≈60-m strain gage) pressure ratings.

The structure of the calibration file corresponding to the PAROSFREQ sensor is similar to the DRUCK. For historic reasons, PAROSFREQ calibration file uses the .drk extension.

- Pressure Sensor Serial Number
- Oscillator Frequency (in Hz)
- U0
- N/A
- N/A
- N/A
- N/A

> Note: The U, Y, C, D, and T coefficients can be found on the Paroscientific calibration sheet.

- Y1 Y2 Y3 N/A
- C1 C2 C3 N/A
- D1 D2 N/A N/A
- T1 T2 T3 T4
- N/A N/A N/A N/A
- N/A N/A N/A N/A

Example – Paroscientific calibration file **p68888.drk**:

```
P68888
12.0000000E+06
5.880670
0.0
0.0
0.0
0.0
-3898.415      -10940.31        0.0          0.0
  224.5927        6.013600   -245.2861        0.0
    0.041219      0.0          0.0            0.0
   27.94067       0.859765    20.65914     26.99304
    0.0           0.0          0.0            0.0
    0.0           0.0          0.0            0.0
```

4. Additional System Commands

This section describes the system commands used for external pressure sensor operation.

4.1. ADPs and Hydras

The following commands apply to ADP and Hydra (ADVOcean) systems that have an external pressure sensor installed.

ExtPressureSensorInstalled Set [NONE|PAROS|DRUCK|PAROSFREQ]
- Selects or disables the external pressure sensor type.
- Set at the factory. Does not need to be changed except in some special cases.
- The external pressure sensor option limits the maximum sampling rate of an ADV to 4 Hz for the PAROS and to 10 Hz for a DRUCK or PAROSFREQ. To collect data at faster rates, you must disable the external pressure sensor option.

PressFreqOffset Set [d]
- Default parameters (in kHz): **0** (for DRUCK); **21** (for PAROSFREQ)
- Sets/displays frequency offset (in kHz).
- This parameter is set at the factory and should not be changed by the user.

PAROS CONT *or* **DRUCK CONT** *or* **PAROSFREQ CONT**
- This command provides a useful tool to verify and troubleshoot the frequency sensor.
- For PAROS sensors:
  - This command continually outputs pressure reading in dbar.
  - If the pressure reading is zero, the connection between the sensor and the processing electronics may be damaged (or open).
- For DRUCK and PAROSFREQ sensors:
  - This command outputs a sample consisting of converted pressure (dbar), temperature (°C), and raw frequency counts (Hz) in the following format:

    ```
    Druck Press =    10.03192    Temp = 22.11    Freq =   8055.674
    ```

  - The DRUCK frequency range (in air) is 7 to 10 kHz; the PAROSFREQ is 35 to 38 kHz.
  - If the frequency reading is zero, or is outside the range, the connection between the sensor and processing electronics may be damaged (or open).
  - If the frequency reading is reasonable, but the corresponding pressure is not, this indicates that the appropriate calibration is not loaded into the processor. Section 5 describes how to load the DRUCK calibration.

Show DRUCK *or* **Show PAROSFREQ**
- Displays DRUCK/PAROSFREQ calibration data in the following format:

```
Druck pressure sensor calibration data
--------------------------------------
SN:     1276950
F0:        1.200e+07
X:    8.4410000e+03
Y:    5.6000000e+02
T0: -1.0000000e+01
D0:  6.2900000e+02
DT: -2.2100000e+00

K00:  1.5962190e+03   K01: -2.6693000e-02
K10:  1.6820332e+00   K11: -1.0395800e-05
K20:  3.9933779e-04   K21: -4.9470601e-09
K30:  8.0327140e-08   K31: -1.4093000e-12
K40:  1.7388157e-11   K41:  2.2691999e-16
K50:  2.5953699e-15   K51:  1.3877999e-19

K02:  3.1005999e-05   K03:  2.6474001e-07
K12:  1.8332999e-08   K13:  8.2459997e-11
K22:  1.6572001e-11   K23: -1.7079999e-14
K32: -7.7020003e-15   K33: -9.9870002e-17
K42: -4.0642002e-18   K43: -1.0678000e-19
K52:  5.3660002e-21   K53: -2.8249999e-23
```

4.2. Argonaut SL/XR

The following command applies to Argonaut SL and XR systems that have an external pressure sensor installed.

ExtPressInstalled [NONE|PAROS|DRUCK]
- Selects or disables the frequency pressure sensor type.
- Set at the factory. Does not need to be changed.

5. Additional Software

This section describes additional software required to use external frequency pressure sensors (DRUCK/PAROSFREQ) with SonTek instruments.

5.1. Downloading and Extracting Druck Calibration: LDDRUCK/GTDRUCK

The **LDDRUCK.EXE** program *loads* the DRUCK/PAROSFREQ calibration file into the instrument's processor. The command syntax is:

```
LDDRUCK [DruckCalFile] [-COM port] [-Baud Rate] [-Address]
```

where

- DruckCalFile is the name of the calibration file (no extension).
- -COM port is the serial port to which the system is connected (1=COM1; 2= COM2).
- -Baud Rate is the communication baud rate setting of the system. If no value is given, the program assumes the default setting of 9600 baud. Acceptable baud rate settings are 1200, 2400, 4800, 9600, 19200, 38400, 57600, and 115200.
- -Address is the address for a RS-485 system.

Example: **LDDRUCK P84567 –p1 –b19200 –a2** will download the file **P84567.DRK** onto the system at address **2** connected to COM port **1** at **19200** baud.

The **GTDRUCK.EXE** program *gets* (downloads) the DRUCK/PAROSFREQ calibration file from the instrument's processor to the user's PC. The command syntax is:

```
GTDRUCK [MyCalFile] [-COM port] [-Baud Rate] [-Address]
```

where

- MyCalFile is the name of the calibration file (no extension).
- -COM port is the serial port to which the system is connected (1=COM1; 2= COM2).
- -Baud Rate is the communication baud rate setting of the system. If no value is given, the program assumes the default setting of 9600 baud. Acceptable baud rate settings are 1200, 2400, 4800, 9600, 19200, 38400, 57600, and 115200.
- -Address is the address for a RS-485 system.

Example: **GTDRUCK B199 –p2 –b19200** will retrieve the calibration data from the system connected to COM port **2** at **19200** baud and store the data into file **B199.DRK**.

5.2. PC-ADP Header Extraction: GADPHDR

During data collection, standard ADPs store mean pressure data (converted into dbars) in the header. PC-ADPs, however, usually profile at much faster rates. As such, the pressure data from the DRUCK or PAROSFREQ sensor is stored in raw frequency counts as a way to increase system performance. The extraction program `GADPHDR.EXE` lets you specify the DRUCK/PAROSFREQ calibration file so the pressure data can be converted into dbars during the data extraction process. The command syntax is:

```
GADPHDR [DataFile] [-P]
```

where

- `DataFile` is the name of the PC-ADP data file being extracted (.adp extension implied).
- `-P` is the name of the pressure sensor calibration file (.drk extension implied).

Example: `GADPHDR MYDATA -Pp87654` will extract header data from the `MYDATA.ADP` data file using DRUCK/PAROSFREQ calibration data from the `p87654.DRK` file. Note: If incorrect calibration data is used, the pressure data will not be correct.

5.3. ADP Wave Data Extraction: GADPWAVE/GADPPRES

To increase system performance when collecting wave or pressure series data, the ADP stores wave and pressure series data in raw frequency counts (DRUCK/PAROSFREQ sensors only). To extract the data, use the `-P` command line option to specify the DRUCK/PAROSFREQ calibration file so the data can be converted to dbars during the data extraction process. Examples:

```
GADPWAVE ADPWAVE -Pp87654
```

will extract wave data from the `ADPWAVE.ADP` using DRUCK/PAROSFREQ calibration from the `p87654.DRK` file.

```
GADPPRES ADPWAVE -Pp87654
```

will extract pressure series data from the `ADPWAVE.ADP` using DRUCK/PAROSFREQ calibration from the `p87654.DRK` file.

Note that in both cases that if incorrect calibration data is used, the output data will be invalid.

5.4. Hydra Data Extraction: GADVTS/GADVHDR

To increase system performance, the Hydra stores pressure series data in raw frequency counts (DRUCK/PAROSFREQ sensors only). To extract pressure series data, use the `-D` command line option to specify the DRUCK/PAROSFREQ calibration file so the data can be converted to dbars during the data extraction process. Examples:

```
GADVTS HYDRAFILE -Dp87654
```

will extract time-series data from the `HYDRAFILE.ADR` using DRUCK/PAROSFREQ calibration from the `p87654.DRK` file.

```
GADVHDR HYDRAFILE -Dp87654
```

will extract header data from the `HYDRAFILE.ADR` using DRUCK/PAROSFREQ calibration from the `p87654.DRK` file.

Note that in both cases that if incorrect calibration data is used, the output data will be invalid.

5.5. Windows Software Support

SonTek Windows-based software offers an alternative to the DOS extraction programs for handling the external pressure sensor calibration data.

5.5.1. Downloading Calibration File Using SonTermW

Starting with v2.0, SonTerm for Windows (*SonTermW*) provides an easy way to load the frequency pressure sensor calibration file into the system processor. Simply establish communication with the system in *SonTermW*, click the **Load Druck Calibration** icon, choose the appropriate file, and the load process will be performed.

5.5.2. Specifying Calibration File When Using ViewHydra

When opening a data file (.adr) with *ViewHydra*, you must supply a sensor calibration file (.drk) to convert pressure data to dbars. If no pressure calibration is provided, all pressure data will be displayed in raw frequency counts. *ViewHydra* lets you save the calibration data in an associated data file workspace, so the calibration data is loaded automatically the next time the data file is opened.

After the data file is loaded, you can select the sensor offset from the processing menu to convert the absolute pressure reading.

1. Run DRUCK/PAROSFREQ in *SonTermW* and make note of the pressure reading with the system in the air (say 10.025 dbar for this example).
2. In the **Processing|Sensor Calibration Settings…** menu, set **Sensor Type** to **Ext Pressure**, and then enter a value of **–10.025** (for this example) in the **Offset** field to convert pressure data into strain gage data (relative to the atmosphere).
3. Now use the **Processing|Recompute Burst Statistics File…** option to propagate the changes into the burst-averaged data.
4. When exiting the program, use the **Save (Overwrite) Workspace** option to store the calibration and offset data. The program will now remember this information for this data set.

5.5.3. Using ViewADP with PCADP Data and Waves

Data collected by a standard ADP stores mean pressure data in dbars; no additional conversion is needed. However, PC-ADP data and ADP wave series data (P-SERIES & PUV-Series) require pressure calibration.

When opening a data file with *ViewADP*, click the **Load ExtPres CalFile** button to specify the calibration file.

Notes:

1. If pressure calibration is not loaded, all pressure data will be displayed as raw frequencies.
2. If pressure calibration data is not loaded, wave data processing is disabled.
3. ViewADP will save the calibration data in the associated data file's workspace. This allows the calibration data to load automatically the next time the data file is opened.