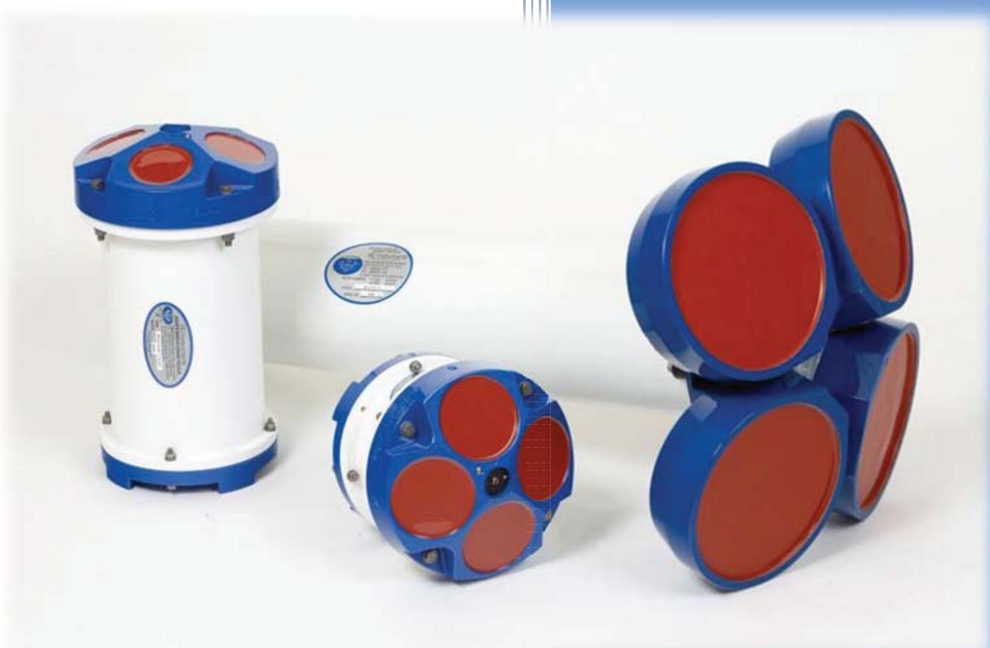
WORKHORSE

MONITOR, SENTINEL, MARINER,
LONG RANGER, AND QUARTERMASTER

COMMANDS AND OUTPUT DATA FORMAT



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Chapter 4

OUTPUT DATA FORMAT

In this chapter, you will learn:

- Choosing a Data Format
- PD0 Output Data Format

PD0 Output Data Format

The following description is for the standard PD0 WorkHorse ADCP output data format. Figure 8 through Figure 15 shows the ASCII and binary data formats for the WorkHorse ADCP PD0 mode. Table 31 through Table 41 defines each field in the output data structure.

The binary output data formats are composed of at least one data type, i.e. a group of bytes all related by their dynamic or field. For instance in the PD0 data format, variables that do not change during the deployment are stored in the Fixed Leader data type of leader ID 0000h, whereas the dynamic variables, except velocities, which dynamically change during the deployment are stored under the Variable Leader data type of leader ID 8000h. This distinction is based on the dynamic; other distinctions are present such as velocity types such as data type of leader ID 0001h which groups all the Water Profile Velocity data and leader ID 0006h stores all Bottom Track Velocity data. The WorkHorse ADCP sends all the data for a given type for all depth cells and all beams before the next data type begins.

The advantage of using the leader ID is that one can simply scan for them as the binary data is received in real time on the serial lines and then use the output data format description table to jump directly to the desired data. The PD0 Header ID is 7F7Fh, which makes it easy to detect. In the PD0 Header are the number of bytes in the ensemble, the number of data types and the offset respective to each data type location in the binary ensemble. This gives you the choice between jumping down to the data type using the offsets or detecting the data type ID after you have detected the header ID.

PD0 is the only binary output data format which provides a Header that describes the data included in the ensemble since some data types presence in the PD0 output are dependent on commands parameters. For example, if the number of Bottom Track pings is 0 (BP0), then there will be no Bottom track data type in the ensemble. The table below shows which data types are always output against command dependable data types:

ALWAYS OUTPUT	**HEADER** (6 BYTES + [2 x No. OF DATA TYPES])
	FIXED LEADER DATA (59 BYTES)
	VARIABLE LEADER DATA (65 BYTES)
WD command WP command	**VELOCITY** (2 BYTES + 8 BYTES PER DEPTH CELL)
	CORRELATION MAGNITUDE (2 BYTES + 4 BYTES PER DEPTH CELL)
	ECHO INTENSITY (2 BYTES + 4 BYTES PER DEPTH CELL)
	PERCENT GOOD (2 BYTES + 4 BYTES PER DEPTH CELL)
	STATUS (2 BYTES + 4 BYTES PER DEPTH CELL)
BP command	**BOTTOM TRACK DATA** (85 BYTES)
ALWAYS OUTPUT	**RESERVED** (2 BYTES)
	CHECKSUM (2 BYTES)

Figure 7. PD0 Standard Output Data Buffer Format

Some data outputs are in bytes per depth cell. For example, if the WN command (number of depth cells) = 30 (default), WD command = WD 111 100 000 (default), WP command > 0, BP command > 0, the required data buffer storage space is 841 bytes per ensemble.

There are seven data types output for this example: Fixed Leader, Variable Leader, Velocity, Correlation Magnitude, Echo Intensity, Percent Good, and Bottom Track.

```
 20  BYTES OF HEADER DATA (6 + [2 x 7 Data Types])
 59  BYTES OF FIXED LEADER DATA (FIXED)
 65  BYTES OF VARIABLE LEADER DATA (FIXED)
242  BYTES OF VELOCITY DATA (2 + 8 x 30)
122  BYTES OF CORRELATION MAGNITUDE DATA (2 + 4 x 30)
122  BYTES OF ECHO INTENSITY (2 + 4 x 30)
122  BYTES OF PERCENT-GOOD DATA (2 + 4 x 30)
 85  BYTES OF BOTTOM TRACK DATA (FIXED)
  2  BYTES OF RESERVED FOR TRDI USE (FIXED)
  2  BYTES OF CHECKSUM DATA (FIXED)
-----------------------------------------------------
841  BYTES OF DATA PER ENSEMBLE
```

WinRiver II and *VmDas* may add additional bytes.

For example, *WinRiver II* does not add any bytes to the Bottom Track data, but does insert data in place of other bytes. The Navigation NMEA strings (up to 275 bytes) are stored in the *r.000 raw data between the Bottom Track data and the Reserved/Checksum data. *WinRiver II* output data format is described in the *WinRiver II* User's Guide.

VmDas adds 92 bytes of Navigation data (data ID 2000 hex) just before the Reserved/Checksum data and a two byte offset in the header for this data type. The ENR file (raw data from the ADCP) does not have these bytes, only the ENS, ENX, STA and LTA files. *VmDas* output data format is described in the *VmDas* User's Guide.

Header Data Format

	BIT POSITIONS								
BYTE	7	6	5	4	3	2	1	0	
1	HEADER ID (7Fh)								
2	DATA SOURCE ID (7Fh)								
3	NUMBER OF BYTES IN ENSEMBLE								LSB
4									MSB
5	SPARE								
6	NUMBER OF DATA TYPES								
7	OFFSET FOR DATA TYPE #1								LSB
8									MSB
9	OFFSET FOR DATA TYPE #2								LSB
10									MSB
11	OFFSET FOR DATA TYPE #3								LSB
12									MSB
↓	(SEQUENCE CONTINUES FOR UP TO N DATA TYPES)								↓
2N+5	OFFSET FOR DATA TYPE #N								LSB
2N+6									MSB

See Table 31 for a description of the fields.

Figure 8. Header Data Format

Header information is the first item sent by the ADCP to the output buffer. The WorkHorse ADCP always sends the Least Significant Byte (LSB) first.

Table 31: Header Data Format

Hex Digit	Binary Byte	Field	Description
1,2	1	HDR ID / Header ID	Stores the header identification byte (7Fh).
3,4	2	HDR ID / Data Source ID	Stores the data source identification byte (7Fh for the WorkHorse ADCP).
5-8	3,4	Bytes / Number of bytes in ensemble	This field contains the number of bytes from the start of the current ensemble up to, but not including, the 2-byte checksum (Figure 15).
9,10	5	Spare	Undefined.
11,12	6	No. DT / Number of Data Types	This field contains the number of data types selected for collection. By default, fixed/variable leader, velocity, correlation magnitude, echo intensity, and percent good are selected for collection. This field will therefore have a value of six (4 data types + 2 for the Fixed/Variable Leader data).
13-16	7,8	Address Offset for Data Type #1 / Offset for Data Type #1	This field contains the internal memory address offset where the WorkHorse ADCP will store information for data type #1 (with this firmware, always the Fixed Leader). Adding "1" to this offset number gives the absolute Binary Byte number in the ensemble where Data Type #1 begins (the first byte of the ensemble is Binary Byte #1).
17-20	9,10	Address Offset for Data Type #2 / Offset for Data Type #2	This field contains the internal memory address offset where the WorkHorse ADCP will store information for data type #2 (with this firmware, always the Variable Leader). Adding "1" to this offset number gives the absolute Binary Byte number in the ensemble where Data Type #2 begins (the first byte of the ensemble is Binary Byte #1).
21-24 thru 2n+13 to 2n+16	11,12 thru 2n+5, 2n+6	Address Offsets for Data Types #3-n / Offset for Data Type #3 through #n	These fields contain internal memory address offset where the WorkHorse ADCP will store information for data type #3 through data type #n. Adding "1" to this offset number gives the absolute Binary Byte number in the ensemble where Data Types #3-n begin (first byte of ensemble is Binary Byte) #1).

Fixed Leader Data Format

BYTE	7	6	5	4	3	2	1	0	
1	FIXED LEADER ID								LSB 00h
2									MSB 00h
3	CPU F/W VER.								
4	CPU F/W REV.								
5	SYSTEM CONFIGURATION								LSB
6									MSB
7	REAL/SIM FLAG								
8	LAG LENGTH								
9	NUMBER OF BEAMS								
10	NUMBER OF CELLS {WN}								
11	PINGS PER ENSEMBLE {WP}								LSB
12									MSB
13	DEPTH CELL LENGTH {WS}								LSB
14									MSB
15	BLANK AFTER TRANSMIT {WF}								LSB
16									MSB
17	PROFILING MODE {WM}								
18	LOW CORR THRESH {WC}								
19	NO. CODE REPS								
20	%GD MINIMUM {WG}								
21	ERROR VELOCITY MAXIMUM {WE}								LSB
22									MSB
23	TPP MINUTES								
24	TPP SECONDS								
25	TPP HUNDREDTHS {TP}								
26	COORDINATE TRANSFORM {EX}								
27	HEADING ALIGNMENT {EA}								LSB
28									MSB
29	HEADING BIAS {EB}								LSB
30									MSB
31	SENSOR SOURCE {EZ}								
32	SENSORS AVAILABLE								
33	BIN 1 DISTANCE								
34									
35	XMIT PULSE LENGTH BASED ON {WT}								LSB
36									MSB

BYTE	BIT POSITIONS 7 6 5 4 3 2 1 0	
37	(starting cell) WP REF LAYER AVERAGE {WL} (ending cell)	LSB
38		MSB
39	FALSE TARGET THRESH {WA}	
40	SPARE	
41	TRANSMIT LAG DISTANCE	LSB
42		MSB
43	CPU BOARD SERIAL NUMBER	MSB
↓		↓
50		LSB
51	SYSTEM BANDWIDTH {WB}	LSB
52		MSB
53	SYSTEM POWER {CQ}	
54	SPARE	
55	INSTRUMENT SERIAL NUMBER	
↓		
58		
59	BEAM ANGLE	

See Table 32 for a description of the fields

Figure 9. Fixed Leader Data Format

Fixed Leader data refers to the non-dynamic WorkHorse ADCP data that only changes when you change certain commands. Fixed Leader data also contain hardware information. The WorkHorse ADCP always sends Fixed Leader data as output data (LSBs first).

Table 32: Fixed Leader Data Format

Hex Digit	Binary Byte	Field	Description
1-4	1,2	FID / Fixed Leader ID	Stores the Fixed Leader identification word (00 00h).
5,6	3	fv / CPU F/W Ver.	Contains the version number of the CPU firmware.
7,8	4	fr / CPU F/W Rev.	Contains the revision number of the CPU firmware.
9-12	5,6	Sys Cfg / System Configuration	This field defines the WorkHorse ADCP hardware configuration. Convert this field (2 bytes, LSB first) to binary and interpret as follows. LSB BITS 7 6 5 4 3 2 1 0 - - - - - 0 0 0 75-kHz SYSTEM - - - - - 0 0 1 150-kHz SYSTEM - - - - - 0 1 0 300-kHz SYSTEM - - - - - 0 1 1 600-kHz SYSTEM - - - - - 1 0 0 1200-kHz SYSTEM - - - - - 1 0 1 2400-kHz SYSTEM - - - - 0 - - - CONCAVE BEAM PAT. - - - - 1 - - - CONVEX BEAM PAT. - - 0 0 - - - - SENSOR CONFIG #1 - - 0 1 - - - - SENSOR CONFIG #2 - - 1 0 - - - - SENSOR CONFIG #3 - 0 - - - - - - XDCR HD NOT ATT. - 1 - - - - - - XDCR HD ATTACHED 0 - - - - - - - DOWN FACING BEAM 1 - - - - - - - UP-FACING BEAM MSB BITS 7 6 5 4 3 2 1 0 - - - - - - 0 0 15E BEAM ANGLE - - - - - - 0 1 20E BEAM ANGLE - - - - - - 1 0 30E BEAM ANGLE - - - - - - 1 1 OTHER BEAM ANGLE 0 1 0 0 - - - - 4-BEAM JANUS CONFIG 0 1 0 1 - - - - 5-BM JANUS CFIG DEMOD) 1 1 1 1 - - - - 5-BM JANUS CFIG.(2 DEMD) Example: Hex 5249 (i.e., hex 49 followed by hex 52) identifies a 150-kHz system, convex beam pattern, down-facing, 30E beam angle, 5 beams (3 demods). Note: XDCR HD ATTACHED refers to whether the chassis and transducer are delivered as one piece; This is not a sensor detect.
13,14	7	PD / Real/Sim Flag	This field is set by default as real data (0).
15,16	8	Lag Length	Lag Length. The lag is the time period between sound pulses. This is varied, and therefore of interest in, at a minimum, for the WM5, WM8 and WM11 and BM7 commands.
17,18	9	#Bm / Number of Beams	Contains the number of beams used to calculate velocity data (not physical beams). The WorkHorse ADCP needs only three beams to calculate water-current velocities. The fourth beam provides an error velocity that determines data validity. If only three beams are available, the WorkHorse ADCP does not make this validity check. Table 37 (Percent-Good Data Format) has more information.
19,20	10	WN / Number of Cells	Contains the number of depth cells over which the WorkHorse ADCP collects data (WN command). Scaling: LSD = 1 depth cell; Range = 1 to 255 depth cells
21-24	11,12	WP / Pings Per Ensemble	Contains the number of pings averaged together during a data ensemble (WP command). If WP = 0, the WorkHorse ADCP does not collect the WD water-profile data. Note: The WorkHorse ADCP automatically extends the ensemble interval (TE) if the product of WP and time per ping (TP) is greater than TE (i.e., if WP x TP > TE). Scaling: LSD = 1 ping; Range = 0 to 16,384 pings

Table 32: Fixed Leader Data Format

Hex Digit	Binary Byte	Field	Description
25-28	13,14	WS / Depth Cell Length	Contains the length of one depth cell (WS command). Scaling: LSD = 1 centimeter; Range = 1 to 6400 cm (210 feet)
29-32	15,16	WF / Blank after Transmit	Contains the blanking distance used by the WorkHorse ADCP to allow the transmit circuits time to recover before the receive cycle begins (WF command). Scaling: LSD = 1 centimeter; Range = 0 to 9999 cm (328 feet)
33,34	17	Signal Processing Mode	Contains the Signal Processing Mode. This field will always be set to 1.
35,36	18	WC / Low Corr Thresh	Contains the minimum threshold of correlation that water-profile data can have to be considered good data (WC command). Scaling: LSD = 1 count; Range = 0 to 255 counts
37,38	19	cr# / No. code reps	Contains the number of code repetitions in the transmit pulse. Scaling: LSD = 1 count; Range = 0 to 255 counts
39,40	20	WG / %Gd Minimum	Contains the minimum percentage of water-profiling pings in an ensemble that must be considered good to output velocity data. Scaling: LSD = 1 percent; Range = 1 to 100 percent
41-44	21,22	WE / Error Velocity Threshold	This field, initially set by the WE command, contains the actual threshold value used to flag water-current data as good or bad. If the error velocity value exceeds this threshold, the WorkHorse ADCP flags all four beams of the affected bin as bad. Scaling: LSD = 1 mm/s; Range = 0 to 5000 mm/s
45,46 47,48 49,50	23 24 25	Minutes Seconds Hundredths	These fields, set by the TP command, contain the amount of time between ping groups in the ensemble. NOTE: The WorkHorse ADCP automatically extends the ensemble interval (set by TE) if (WP x TP > TE).

51,52	26	EX / Coord Transform	Contains the coordinate transformation processing parameters (EX command). These firmware switches indicate how the WorkHorse ADCP collected data.
			`xxx00xxx = NO TRANSFORMATION (BEAM COORDINATES)`
			`xxx01xxx = INSTRUMENT COORDINATES`
			`xxx10xxx = SHIP COORDINATES`
			`xxx11xxx = EARTH COORDINATES`
			`xxxxx1xx = TILTS (PITCH AND ROLL) USED IN SHIP OR EARTH TRANSFORMATION`
			`xxxxxx1x = 3-BEAM SOLUTION USED IF ONE BEAM IS BELOW THE CORRELATION THRESHOLD SET BY THE WC command`
			`xxxxxxx1 = BIN MAPPING USED`

53-56	27,28	EA / Heading Alignment	Contains a correction factor for physical heading misalignment (EA command). Scaling: LSD = 0.01 degree; Range = -179.99 to 180.00 degrees
57-60	29,30	EB / Heading Bias	Contains a correction factor for electrical/magnetic heading bias (EB command). Scaling: LSD = 0.01 degree; Range = -179.99 to 180.00 degrees

Table 32: Fixed Leader Data Format

Hex Digit	Binary Byte	Field	Description

61,62	31	EZ / Sensor Source	Contains the selected source of environmental sensor data (EZ command). These firmware switches indicate the following.
			`FIELD        DESCRIPTION`
			`x1xxxxxx = CALCULATES EC (SPEED OF SOUND) FROM ED, ES, AND ET`
			`xx1xxxxx = USES ED FROM DEPTH SENSOR`
			`xxx1xxxx = USES EH FROM TRANSDUCER HEADING SENSOR`
			`xxxx1xxx = USES EP FROM TRANSDUCER PITCH SENSOR`
			`xxxxx1xx = USES ER FROM TRANSDUCER ROLL SENSOR`
			`xxxxxx1x = USES ES (SALINITY) FROM CONDUCTIVITY SENSOR`
			`xxxxxxx1 = USES ET FROM TRANSDUCER TEMPERATURE SENSOR`
			NOTE: If the field = 0, or if the sensor is not available, the WorkHorse ADCP uses the manual command setting. If the field = 1, the WorkHorse ADCP uses the reading from the internal sensor or an external synchro sensor (only applicable to heading, roll, and pitch). Although you can enter a “2” in the EZ command string, the WorkHorse ADCP only displays a 0 (manual) or 1 (int/ext sensor).

63,64	32	Sensor Avail	This field reflects which sensors are available. The bit pattern is the same as listed for the EZ command (above).
65-68	33,34	dis1 / Bin 1 distance	This field contains the distance to the middle of the first depth cell (bin). This distance is a function of depth cell length (WS), the profiling mode (WM), the blank after transmit distance (WF), and speed of sound. Scaling: LSD = 1 centimeter; Range = 0 to 65535 cm (2150 feet)
69-72	35,36	WT Xmit pulse length	This field, set by the WT command, contains the length of the transmit pulse. When the WorkHorse ADCP receives a <BREAK> signal, it sets the transmit pulse length as close as possible to the depth cell length (WS command). This means the WorkHorse ADCP uses a WT command of zero. However, the WT field contains the actual length of the transmit pulse used. Scaling: LSD = 1 centimeter; Range = 0 to 65535 cm (2150 feet)
73,74 75,76	37,38	WL / WP Ref Lyr Avg (Starting cell, Ending cell)	Contains the starting depth cell (LSB, byte 37) and the ending depth cell (MSB, byte 38) used for water reference layer averaging (WL command). Scaling: LSD = 1 depth cell; Range = 1 to 128 depth cells
77,78	39	WA / False Target Threshold	Contains the threshold value used to reject data received from a false target, usually fish (WA command). Scaling: LSD = 1 count; Range = 0 to 255 counts (255 disables)
79,80	40	Spare	Contains the CX command setting. Range = 0 to 5
81-84	41,42	LagD / Transmit lag distance	This field, determined mainly by the setting of the WM command, contains the distance between pulse repetitions. Scaling: LSD = 1 centimeter; Range = 0 to 65535 centimeters
85-100	43-50	CPU Board Serial Number	Contains the serial number of the CPU board. The CPU Board Serial number is stored in Big Endian (MSB sent first).
101-104	51-52	WB / System Bandwidth	Contains the WB command setting. Range = 0 to 1
105-106	53	System Power	Contains the CQ command setting for WorkHorse ADCP Monitor/Sentinel/Long Ranger ADCPs. Range 0 to 255.
107-108	54	Spare	Spare
109-116	55-58	Serial #	Instrument serial number
117 -118	59	Beam Angle	Beam angle

Variable Leader Data Format

BYTE	BIT POSITIONS 7 6 5 4 3 2 1 0	
1	VARIABLE LEADER ID	80h
2		00h
3	ENSEMBLE NUMBER	LSB
4		MSB
5	RTC YEAR {TS}	
6	RTC MONTH {TS}	
7	RTC DAY {TS}	
8	RTC HOUR {TS}	
9	RTC MINUTE {TS}	
10	RTC SECOND {TS}	
11	RTC HUNDREDTHS {TS}	
12	ENSEMBLE # MSB	
13	BIT RESULT	LSB
14		MSB
15	SPEED OF SOUND {EC}	LSB
16		MSB
17	DEPTH OF TRANSDUCER {ED}	LSB
18		MSB
19	HEADING {EH}	LSB
20		MSB
21	PITCH (TILT 1) {EP}	LSB
22		MSB
23	ROLL (TILT 2) {ER}	LSB
24		MSB
25	SALINITY {ES}	LSB
26		MSB
27	TEMPERATURE {ET}	LSB
28		MSB
29	MPT MINUTES	
30	MPT SECONDS	
31	MPT HUNDREDTHS	
32	HDG STD DEV	
33	PITCH STD DEV	
34	ROLL STD DEV	

BYTE	BIT POSITIONS 7	6	5	4	3	2	1	0	
35	ADC CHANNEL 0								
36	ADC CHANNEL 1								
37	ADC CHANNEL 2								
38	ADC CHANNEL 3								
39	ADC CHANNEL 4								
40	ADC CHANNEL 5								
41	ADC CHANNEL 6								
42	ADC CHANNEL 7								
43	ERROR STATUS WORD (ESW) {CY}								LSB
44									
45									
46									MSB
47	SPARE								
48									
49	PRESSURE								LSB
50									
51									
52									MSB
53	PRESSURE SENSOR VARIANCE								LSB
54									
55									
56									MSB
57	SPARE								
58	RTC CENTURY								
59	RTC YEAR								
60	RTC MONTH								
61	RTC DAY								
62	RTC HOUR								
63	RTC MINUTE								
64	RTC SECOND								
65	RTC HUNDREDTH								

See Table 33 for a description of the fields.

Figure 10. Variable Leader Data Format

Variable Leader data refers to the dynamic WorkHorse ADCP data (from clocks/sensors) that change with each ping. The WorkHorse ADCP always sends Variable Leader data as output data (LSBs first).

Table 33: Variable Leader Data Format

Hex Digit	Binary Byte	Field	Description
1-4	1,2	VID / Variable Leader ID	Stores the Variable Leader identification word (80 00h).

5-8	3,4	Ens / Ensemble Number	This field contains the sequential number of the ensemble to which the data in the output buffer apply.
			Scaling: LSD = 1 ensemble; Range = 1 to 65,535 ensembles
			NOTE: The first ensemble collected is #1. At “rollover,” we have the following sequence:
			`1 = ENSEMBLE NUMBER 1`
			`↓`
			`65535 = ENSEMBLE NUMBER 65,535 | ENSEMBLE`
			`0 = ENSEMBLE NUMBER 65,536 | #MSB FIELD`
			`1 = ENSEMBLE NUMBER 65,537 | (BYTE 12) INCR.`

9,10	5	RTC Year	These fields contain the time from the WorkHorse ADCP’s real-time clock (RTC) that the current data ensemble began. The TS command (Set Real-Time Clock) initially sets the clock. The WorkHorse ADCP does account for leap years.
11,12	6	RTC Month	
13,14	7	RTC Day	
15,16	8	RTC Hour	
17,18	9	RTC Minute	
19,22	10	RTC Second	
21,22	11	RTC Hundredths	
23-24	12	Ensemble # MSB	This field increments each time the Ensemble Number field (bytes 3,4) “rolls over.” This allows ensembles up to 16,777,215. See Ensemble Number field above.

25-28	13,14	BIT / BIT Result	This field contains the results of the WorkHorse ADCP’s Built-in Test function. A zero code indicates a successful BIT result.
			`BYTE 13   BYTE 14  (BYTE 14 RESERVED FOR FUTURE USE)`
			`1xxxxxxx xxxxxxxx = RESERVED`
			`x1xxxxxx xxxxxxxx = RESERVED`
			`xx1xxxxx xxxxxxxx = RESERVED`
			`xxx1xxxx xxxxxxxx = DEMOD 1 ERROR`
			`xxxx1xxx xxxxxxxx = DEMOD 0 ERROR`
			`xxxxx1xx xxxxxxxx = RESERVED`
			`xxxxxx1x xxxxxxxx = TIMING CARD ERROR`
			`xxxxxxx1 xxxxxxxx = RESERVED`

29-32	15,16	EC / Speed of Sound	Contains either manual or calculated speed of sound information (EC command). Scaling: LSD = 1 meter per second; Range = 1400 to 1600 m/s
33-36	17,18	ED / Depth of Transducer	Contains the depth of the transducer below the water surface (ED command). This value may be a manual setting or a reading from a depth sensor. Scaling: LSD = 1 decimeter; Range = 1 to 65535 decimeters
37-40	19,20	EH / Heading	Contains the WorkHorse ADCP heading angle (EH command). This value may be a manual setting or a reading from a heading sensor. Scaling: LSD = 0.01 degree; Range = 000.00 to 359.99 degrees
41-44	21,22	EP / Pitch (Tilt 1)	Contains the WorkHorse ADCP pitch angle (EP command). This value may be a manual setting or a reading from a tilt sensor. Positive values mean that Beam #3 is spatially higher than Beam #4. Scaling: LSD = 0.01 degree; Range = -20.00 to +20.00 degrees
45-48	23,24	ER / Roll (Tilt 2)	Contains the WorkHorse ADCP roll angle (ER command). This value may be a manual setting or a reading from a tilt sensor. For up-facing WorkHorse ADCPs, positive values mean that Beam #2 is spatially higher than Beam #1. For down-facing WorkHorse ADCPs, positive values mean that Beam #1 is spatially higher than Beam #2. Scaling: LSD = 0.01 degree; Range = -20.00 to +20.00 degrees

Table 33: Variable Leader Data Format

Hex Digit	Binary Byte	Field	Description
49-52	25,26	ES / Salinity	Contains the salinity value of the water at the transducer head (ES command). This value may be a manual setting or a reading from a conductivity sensor. Scaling: LSD = 1 part per thousand; Range = 0 to 40 ppt
53-56	27,28	ET / Temperature	Contains the temperature of the water at the transducer head (ET command). This value may be a manual setting or a reading from a temperature sensor. Scaling: LSD = 0.01 degree; Range = -5.00 to +40.00 degrees
57,58	29	MPT minutes	This field contains the Minimum Pre-Ping Wait Time between ping groups in the ensemble.
59,60	30	MPT seconds	
61,62	31	MPT hundredths	
63,64	32	H/Hdg Std Dev	These fields contain the standard deviation (accuracy) of the heading and tilt angles from the gyrocompass/pendulums. Scaling (Heading): LSD = 1°; Range = 0 to 180° Scaling (Tilts): LSD = 0.1°; Range = 0.0 to 20.0°
65,66	33	P/Pitch Std Dev	
67,68	34	R/Roll Std Dev	

69-70	35	ADC Channel 0	These fields contain the outputs of the Analog-to-Digital Converter (ADC) located on the DSP board. The ADC sequentially samples one of the eight channels per ping group (the number of ping groups per ensemble is the maximum of the WP). These fields are zeroed at the beginning of the deployment and updated each ensemble at the rate of one channel per ping group. For example, if the ping group size is 5, than:
			`END OF ENSEMBLE No.  CHANNELS UPDATED`
			`Start                All channels = 0`
			`1                    0, 1, 2, 3, 4`
			`2                    5, 6, 7, 0, 1`
			`3                    2, 3, 4, 5, 6`
			`4                    7, 0, 1, 2, 3`
			`↓                    ↓`
			Here is the description for each channel:
			`CHANNEL  DESCRIPTION`
			`0        XMIT CURRENT`
			`1        XMIT VOLTAGE`
			`2        AMBIENT TEMP`
			`3        PRESSURE (+)`
			`4        PRESSURE (-)`
			`5        ATTITUDE TEMP`
			`6        ATTITUDE`
			`7        CONTAMINATION SENSOR`
			Note that the ADC values may be “noisy” from sample-to-sample, but are useful for detecting long-term trends. See Converting ADC Channels for more information.

71-72	36	ADC Channel 1	
73-74	37	ADC Channel 2	
75-76	38	ADC Channel 3	
77-78	39	ADC Channel 4	
79-80	40	ADC Channel 5	
81-82	41	ADC Channel 6	
83-84	42	ADC Channel 7	

85-86	43	Error Status Word	Contains the long word containing the bit flags for the CY Command. The ESW is cleared (set to zero) between each ensemble.
			Note that each number above represents one bit set – they may occur in combinations. For example, if the long word value is 0000C000 (hexadecimal), than it indicates that both a cold wake-up (0004000) and an unknown wake-up (00008000) occurred.
			Low 16 BITS
			LSB
			`BITS 07 06 05 04 03 02 01 00`
			`x  x  x  x  x  x  x  1  Bus Error exception`
			`x  x  x  x  x  x  1  x  Address Error exception`
			`x  x  x  x  x  1  x  x  Illegal Instruction exception`
			`x  x  x  x  1  x  x  x  Zero Divide exception`
			`x  x  x  1  x  x  x  x  Emulator exception`
			`x  x  1  x  x  x  x  x  Unassigned exception`
			`x  1  x  x  x  x  x  x  Watchdog restart occurred`
			`1  x  x  x  x  x  x  x  Battery Saver power`

Table 33: Variable Leader Data Format

<table>
<tr><th>Hex Digit</th><th>Binary Byte</th><th>Field</th><th>Description</th></tr>
<tr><td>87-88</td><td>44</td><td></td><td>Low 16 BITS
MSB<pre>
BITS 15 14 13 12 11 10 09 08
      x x x x x x x 1 Pinging
      x x x x x x 1 x Not Used
      x x x x x 1 x x Not Used
      x x x x 1 x x x Not Used
      x x x 1 x x x x Not Used
      x x 1 x x x x x Not Used
      x 1 x x x x x x Cold Wakeup occurred
      1 x x x x x x x Unknown Wakeup occurred
</pre></td></tr>
<tr><td>89-90</td><td>45</td><td></td><td>High 16 BITS
LSB<pre>
BITS 23 22 21 20 19 18 17 16
      x x x x x x x 1 Clock Read error occurred
      x x x x x x 1 x Unexpected alarm
      x x x x x 1 x x Clock jump forward
      x x x x 1 x x x Clock jump backward
      x x x 1 x x x x Not Used
      x x 1 x x x x x Not Used
      x 1 x x x x x x Not Used
      1 x x x x x x x Not Used
</pre></td></tr>
<tr><td>91-92</td><td>46</td><td></td><td>High 16 BITS
MSB<pre>
BITS 31 30 29 28 27 26 25 24
      x x x x x x x 1 Not Used
      x x x x x x 1 x Not Used
      x x x x x 1 x x Not Used
      x x x x 1 x x x Power Fail (Unrecorded)
      x x x 1 x x x x Spurious level 4 intr (DSP)
      x x 1 x x x x x Spurious level 5 intr (UART)
      x 1 x x x x x x Spurious level 6 intr (CLOCK)
      1 x x x x x x x Level 7 interrupt occurred
</pre></td></tr>
<tr><td>93-96</td><td>47-48</td><td>Reserved</td><td>Reserved for TRDI use.</td></tr>
<tr><td>97-104</td><td>49-52</td><td>Pressure</td><td>Contains the pressure of the water at the transducer head relative to one atmosphere (sea level). Output is in deca-pascals (see How Does the WorkHorse ADCP Sample Depth and Pressure).
Scaling: LSD=1 deca-pascal; Range=0 to ± 2147483648 deca-pascals</td></tr>
<tr><td>105-112</td><td>53-56</td><td>Pressure variance</td><td>Contains the variance (deviation about the mean) of the pressure sensor data. Output is in deca-pascals.
Scaling: LSD=1 deca-pascal; Range=0 to ± 2147483648 deca-pascals</td></tr>
<tr><td>113-114</td><td>57</td><td>Spare</td><td>Spare</td></tr>
<tr><td>115-116</td><td>58</td><td>RTC Century</td><td rowspan="8">These fields contain the time from the WorkHorse ADCP’s Y2K compliant real-time clock (RTC) that the current data ensemble began. The TT command (Set Real-Time Clock) initially sets the clock. The WorkHorse ADCP does account for leap years.</td></tr>
<tr><td>117-118</td><td>59</td><td>RTC Year</td></tr>
<tr><td>119-120</td><td>60</td><td>RTC Month</td></tr>
<tr><td>121-122</td><td>61</td><td>RTC Day</td></tr>
<tr><td>123-124</td><td>62</td><td>RTC Hour</td></tr>
<tr><td>125-126</td><td>63</td><td>RTC Minute</td></tr>
<tr><td>127-128</td><td>64</td><td>RTC Seconds</td></tr>
<tr><td>129-130</td><td>65</td><td>RTC Hundredths</td></tr>
</table>

Converting ADC Channels

The ADC channels in the Workhorse ADCP are defined as follows:

Channel	Signal
0	Transmit current
1	Transmit voltage
2	Ambient Temperature
3	Pressure High (+)
4	Pressure Low (-)
5	Attitude Temperature
6	Attitude Mux (X & Y tilts)
7	Contamination Sensor

Note that while each Workhorse ADC channel is 16-bits, and the full 16-bit values are used for most internal calculations (except for IXmt and VXmt), the raw counts that get output in the PD0 data are truncated to just the upper 8-bits. It is not possible to get the exact value from the ADC outputs.

XMT Voltage and Current Channels:

The Workhorse uses a frequency-indexed table to set the scale factors for the Transmit voltage and Transmit current ADC channels:

Transmit voltage	Transmit current	Frequency (kHz)
2092719	43838	76.8
592157	11451	153.6
592157	11451	307.2
380667	11451	614.4
253765	11451	1228.8
253765	11451	2457.6

The transmit voltage and current values are calculated for the built-in-test by multiplying the ADC upper 8-bit value by the scale factor (they are very rough values). However, the transmit voltage and current measurements are not necessarily accurate, since the sampling is not synchronized to the phasing of the inputs. The voltage and current tables are scaled by 1000000.

Examples (for a 600 kHz WorkHorse ADCP):

Transmit Voltage:

(90 counts * 380667) / 1000000 → 34.26 Volts

Transmit Current:

(103 counts * 11451) / 1000000 → 1.795 Amps

Temperature Channels:

The temperature values are produced by plugging the 16-bit raw ADC count value into a second-order polynomial whose coefficients are hard-coded, plus an additional offset that is observed as part of the PS0 command output:

Temperature = offset + ((a3*x + a2)*x + a1)*x + a0

where:

a0 = 9.82697464E1
a1 = -5.86074151382E-3
a2 = 1.60433886495E-7
a3 = -2.32924716883E-12

Pressure Channel:

Pressure sensor internal factory reference points only; no user support.

Attitude Mux Channel:

This channel is multiplexed between the X and Y tilt signals, and the ADC values for this channel in the output data are therefore not meaningful.

Contamination Sensor:

This data is not used. The readings are generally not consistent.

How Does the WorkHorse ADCP Sample Depth and Pressure?

The WorkHorse ADCP has two options for depth. The first is to use the fixed value the user inputs into the WorkHorse through the ED command. The second is to calculate the depth based on the pressure sensor that is in the WorkHorse transducer. The WorkHorse will store both the depth (fixed or calculated) AND the pressure sensor raw kpa output.

The *WinADCP* program detects in the WorkHorse data set whether an external pressure sensor or a fixed value have been used for the depth calculation. If a fixed value is used then it will display/export the depth as found in the WorkHorse data. If a pressure sensor has been used then it will calculate the depth itself and display/export that value.

1. For each ping, the ADC samples the pressure sensor five times and averages the data. This is an attempt to reduce the Standard Deviation.
2. Using the Pressure coefficients, the pressure data from the ADC is converted to kPa.
3. That data is converted to dm and corrected for salinity with the following equation:

   Depth (dm) = Pressure(kPa) * (1.02-0.00069*ES), where ES is the Salinity setting.

   This is the depth value recorded in the PD0 variable leader when the WH is fitted with a pressure sensor and that the EZ command is set to EZx1xxxxx.
4. The pressure data is converted from kPa to deca-Pascals by multiplying it by 100. This value in deca-Pascals is recorded in the PD0 variable leader data.

Converting kpa to Depth

The formula for converting kpa to depth (using *WinADCP*) is as follows:

(kpa(1.02-0.00069*Salinity)*(1000/Fresh Water Density))/10

Velocity Data Format

	BIT POSITIONS								
BYTE	7/S	6	5	4	3	2	1	0	
1	VELOCITY ID								LSB 00h
2									MSB 01h
3	DEPTH CELL #1, VELOCITY 1								LSB
4									MSB
5	DEPTH CELL #1, VELOCITY 2								LSB
6									MSB
7	DEPTH CELL #1, VELOCITY 3								LSB
8									MSB
9	DEPTH CELL #1, VELOCITY 4								LSB
10									MSB
11	DEPTH CELL #2, VELOCITY 1								LSB
12									MSB
13	DEPTH CELL #2, VELOCITY 2								LSB
14									MSB
15	DEPTH CELL #2, VELOCITY 3								LSB
16									MSB
17	DEPTH CELL #2, VELOCITY 4								LSB
18									MSB
↓	(SEQUENCE CONTINUES FOR UP TO 128 CELLS)								↓
1019	DEPTH CELL #128, VELOCITY 1								LSB
1020									MSB
1021	DEPTH CELL #128, VELOCITY 2								LSB
1022									MSB
1023	DEPTH CELL #128, VELOCITY 3								LSB
1024									MSB
1025	DEPTH CELL #128, VELOCITY 4								LSB
1026									MSB

See Table 34 for description of fields

Figure 11. Velocity Data Format

The number of depth cells is set by the WN command.

The WorkHorse ADCP packs velocity data for each depth cell of each beam into a two-byte, two's-complement integer [-32768, 32767] with the LSB sent first. The WorkHorse ADCP scales velocity data in millimeters per second (mm/s). A value of –32768 (8000h) indicates bad velocity values.

All velocities are relative based on a stationary instrument. To obtain absolute velocities, algebraically remove the velocity of the instrument. For example,

```
RELATIVE WATER CURRENT VELOCITY:    EAST 650 mm/s
INSTRUMENT VELOCITY            : (-) EAST 600 mm/s
ABSOLUTE WATER VELOCITY        :     EAST  50 mm/s
```

The setting of the EX command (Coordinate Transformation) determines how the WorkHorse ADCP references the velocity data as shown below.

EX-CMD	COORD SYS	VEL 1	VEL 2	VEL 3	VEL 4
EX00xxx	BEAM	TO BEAM 1	TO BEAM 2	TO BEAM 3	TO BEAM 4
EX01xxx	INSTRUMENT	Bm1-Bm2	Bm4-Bm3	TO XDUCER	ERR VEL
EX10xxx	SHIP	PRT-STBD	AFT-FWD	TO SURFACE	ERR VEL
EX11xxx	EARTH	TO EAST	TO NORTH	TO SURFACE	ERR VEL

Positive values indicate water movement toward the ADCP.

For Horizontal ADCP systems, use the following table.

EX-CMD	COORD SYS	VEL 1	VEL 2	VEL 3	VEL 4
EX00xxx	BEAM	TO BEAM 1	TO BEAM 2	TO BEAM 3	0
EX01xxx	INST	X AXIS	Y AXIS	0	ERROR VEL
EX10xxx	SHIP	X AXIS	Y AXIS	VERTICAL	ERROR VEL (tilt applied)
EX11xxx	EARTH	EAST	NORTH	VERTICAL	ERROR VEL (heading applied)

Positive values indicate water movement toward the ADCP.

Table 34: Velocity Data Format

Hex Digit	Binary Byte	Field	Description
1-4	1,2	Velocity ID	Stores the velocity data identification word (00 01h).
5-8	3,4	Depth Cell 1, Velocity 1	Stores velocity data for depth cell #1, velocity 1. See above.
9-12	5,6	Depth Cell 1, Velocity 2	Stores velocity data for depth cell #1, velocity 2. See above.
13-16	7,8	Depth Cell 1, Velocity 3	Stores velocity data for depth cell #1, velocity 3. See above.
17-20	9,10	Depth Cell 1, Velocity 4	Stores velocity data for depth cell #1, velocity 4. See above.
21-2052	11-1026	Cells 2 – 128 (if used)	These fields store the velocity data for depth cells 2 through 128 (depending on the setting of the WN command). These fields follow the same format as listed above for depth cell 1.

Correlation Magnitude, Echo Intensity, Percent-Good, and Status Data Format

BYTE	7/S	6	5	4	3	2	1	0	
	BIT POSITIONS								
1	ID CODE								LSB
2									MSB
3	DEPTH CELL #1, FIELD #1								
4	DEPTH CELL #1, FIELD #2								
5	DEPTH CELL #1, FIELD #3								
6	DEPTH CELL #1, FIELD #4								
7	DEPTH CELL #2, FIELD #1								
8	DEPTH CELL #2, FIELD #2								
9	DEPTH CELL #2, FIELD #3								
10	DEPTH CELL #2, FIELD #4								
↓	(SEQUENCE CONTINUES FOR UP TO 128 BINS)								↓
511	DEPTH CELL #128, FIELD #1								
512	DEPTH CELL #128, FIELD #2								
513	DEPTH CELL #128, FIELD #3								
514	DEPTH CELL #128, FIELD #4								

See Table 35 through Table 37 for a description of the fields.

Figure 12. Correlation Magnitude, Echo Intensity, Percent-Good, and Status Data Format

The number of depth cells is set by the WN command.

Correlation magnitude data give the magnitude of the normalized echo autocorrelation at the lag used for estimating the Doppler phase change. The WorkHorse ADCP represents this magnitude by a linear scale between 0 and 255, where 255 is perfect correlation (i.e., a solid target). A value of zero indicates bad correlation values.

Table 35: Correlation Magnitude Data Format

Hex Digit	Binary Byte	Field	Description
1-4	1,2	ID Code	Stores the correlation magnitude data identification word (00 02h).
5,6	3	Depth Cell 1, Field 1	Stores correlation magnitude data for depth cell #1, beam #1. See above.
7,8	4	Depth Cell 1, Field 2	Stores correlation magnitude data for depth cell #1, beam #2. See above.
9,10	5	Depth Cell 1, Field 3	Stores correlation magnitude data for depth cell #1, beam #3. See above.
11,12	6	Depth Cell 1, Field 4	Stores correlation magnitude data for depth cell #1, beam #4. See above.
13 – 1028	7 – 514	Cells 2 – 128 (if used)	These fields store correlation magnitude data for depth cells 2 through 128 (depending on the WN command) for all four beams. These fields follow the same format as listed above for depth cell 1.

The echo intensity scale factor is about 0.45 dB per WorkHorse ADCP count. The WorkHorse ADCP does not directly check for the validity of echo intensity data.

Table 36: Echo Intensity Data Format

Hex Digit	Binary Byte	Field	Description
1 – 4	1,2	ID Code	Stores the echo intensity data identification word (00 03h).
5,6	3	Depth Cell 1, Field 1	Stores echo intensity data for depth cell #1, beam #1. See above.
7,8	4	Depth Cell 1, Field 2	Stores echo intensity data for depth cell #1, beam #2. See above.
9,10	5	Depth Cell 1, Field 3	Stores echo intensity data for depth cell #1, beam #3. See above.
11,12	6	Depth Cell 1, Field 4	Stores echo intensity data for depth cell #1, beam #4. See above.
13 – 1028	7 – 514	Cells 2 – 128 (if used)	These fields store echo intensity data for depth cells 2 through 128 (depending on the WN command) for all four beams. These fields follow the same format as listed above for depth cell 1.

The percent-good data field is a data-quality indicator that reports the percentage (0 to 100) of good data collected for each depth cell of the velocity profile. The setting of the EX command (Coordinate Transformation) determines how the WorkHorse ADCP references percent-good data as shown below.

EX command	Coord. Sys	Velocity 1	Velocity 2	Velocity 3	Velocity 4
		Percentage Of Good Pings For:			
		Beam 1	BEAM 2	BEAM 3	BEAM 4
xxx00xxx	Beam	Percentage Of:			
xxx01xxx	Instrument	3-Beam Transformations (note 1)	Transformations Rejected (note 2)	More Than One Beam Bad In Bin	4-Beam Transformations
xxx10xxx	Ship				
xxx11xxx	Earth				

Note 1. Because profile data did not exceed correlation threshold (WC command).

Note 2. Because the error velocity threshold was exceeded (WE command).

At the start of the velocity profile, the backscatter echo strength is typically high on all four beams. Under this condition, the ADCP uses all four beams to calculate the orthogonal and error velocities. As the echo returns from far away depth cells, echo intensity decreases. At some point, the echo will be weak enough on any given beam to cause the ADCP to reject some of its depth cell data. This causes the ADCP to calculate velocities with three beams instead of four beams. When the ADCP does 3-beam solutions, it stops calculating the error velocity because it needs four beams to do this. At some further depth cell, the ADCP rejects all cell data because of the weak echo. As an example, let us assume depth cell 60 has returned the following percent-good data.

```
FIELD #1 = 50, FIELD #2 = 5, FIELD #3 = 0, FIELD #4 = 45
```

If the EX command was set to collect velocities in BEAM coordinates, the example values show the percentage of pings having good solutions in cell 60 for each beam based on the Low Correlation Threshold (WC command). Here, beam 1=50%, beam 2=5%, beam 3=0%, and beam 4=45%. These are neither typical nor desired percentages. Typically, you would want all four beams to be about equal and greater than 25%.

On the other hand, if velocities were collected in Instrument, Ship, or Earth coordinates, the example values show:

Field 1 – Percentage of good 3-beam solutions – Shows percentage of successful velocity calculations (50%) using 3-beam solutions because the correlation threshold (WC command) was not exceeded.

Field 2 – Percentage of transformations rejected – Shows percent of error velocity (5%) that was less than the WE command setting. WE has a default of 5000 mm/s. This large WE setting effectively prevents the ADCP from rejecting data based on error velocity.

Field 3 – Percentage of more than one beam bad in bin – 0% of the velocity data were rejected because not enough beams had good data.

Field 4 – Percentage of good 4-beam solutions – 45% of the velocity data collected during the ensemble for depth cell 60 were calculated using four beams.

Table 37: Percent-Good Data Format

Hex Digit	Binary Byte	Field	Description
1-4	1,2	ID Code	Stores the percent-good data identification word (00 04h).
5,6	3	Depth cell 1, Field 1	Stores percent-good data for depth cell #1, field 1. See above.
7,8	4	Depth cell 1, Field 2	Stores percent-good data for depth cell #1, field 2. See above.
9,10	5	Depth cell 1, Field 3	Stores percent-good data for depth cell #1, field 3. See above.
11,12	6	Depth cell 1, Field 4	Stores percent-good data for depth cell #1, field 4. See above.
13-1028	7-514	Depth cell 2 – 128 (if used)	These fields store percent-good data for depth cells 2 through 128 (depending on the WN command), following the same format as listed above for depth cell 1.

These fields contain information about the status and quality of ADCP data. A value of 0 means the measurement was good. A value of 1 means the measurement was bad.

Table 38: Status Data Format

Hex Digit	Binary Byte	Field	Description
1-4	1,2	ID Code	Stores the status data identification word (00 05h).
5,6	3	Depth cell 1, Field 1	Stores status data for depth cell #1, beam #1. See above.
7,8	4	Depth cell 1, Field 2	Stores status data for depth cell #1, beam #2. See above.
9,10	5	Depth cell 1, Field 3	Stores status data for depth cell #1, beam #3. See above.
11,12	6	Depth cell 1, Field 4	Stores status data for depth cell #1, beam #4. See above.
13-1028	7-514	Depth cell 2 – 128 (if used)	These fields store status data for depth cells 2 through 128 (depending on the WN command) for all four beams. These fields follow the same format as listed above for depth cell 1.

Bottom-Track Data Format

BYTE	7/S	6	5	4	3	2	1	0	
	BIT POSITIONS								
1	BOTTOM-TRACK ID								LSB 00h
2									MSB 06h
3	BT PINGS PER ENSEMBLE {BP}								LSB
4									MSB
5	BT DELAY BEFORE RE-ACQUIRE {BD}								LSB
6									MSB
7	BT CORR MAG MIN {BC}								
8	BT EVAL AMP MIN {BA}								
9	BT PERCENT GOOD MIN {BG}								
10	BT MODE {BM}								
11	BT ERR VEL MAX {BE}								LSB
12									MSB
13	Reserved								
14									
15									
16									
17	BEAM#1 BT RANGE								LSB
18									MSB
19	BEAM#2 BT RANGE								LSB
20									MSB
21	BEAM#3 BT RANGE								LSB
22									MSB
23	BEAM#4 BT RANGE								LSB
24									MSB
25	BEAM#1 BT VEL								LSB
26									MSB
27	BEAM#2 BT VEL								LSB
28									MSB
29	BEAM#3 BT VEL								LSB
30									MSB
31	BEAM#4 BT VEL								LSB
32									MSB
33	BEAM#1 BT CORR.								
34	BEAM#2 BT CORR.								
35	BEAM#3 BT CORR.								
36	BEAM#4 BT CORR.								

BYTE	BIT POSITIONS 7/S	6	5	4	3	2	1	0	
37	BEAM#1 EVAL AMP								
38	BEAM#2 EVAL AMP								
39	BEAM#3 EVAL AMP								
40	BEAM#4 EVAL AMP								
41	BEAM#1 BT %GOOD								
42	BEAM#2 BT %GOOD								
43	BEAM#3 BT %GOOD								
44	BEAM#4 BT %GOOD								
45	REF LAYER MIN {BL}								LSB
46									MSB
47	REF LAYER NEAR {BL}								LSB
48									MSB
49	REF LAYER FAR {BL}								LSB
50									MSB
51	BEAM#1 REF LAYER VEL								LSB
52									MSB
53	BEAM #2 REF LAYER VEL								LSB
54									MSB
55	BEAM #3 REF LAYER VEL								LSB
56									MSB
57	BEAM #4 REF LAYER VEL								LSB
58									MSB
59	BM#1 REF CORR								
60	BM#2 REF CORR								
61	BM#3 REF CORR								
62	BM#4 REF CORR								
63	BM#1 REF INT								
64	BM#2 REF INT								
65	BM#3 REF INT								
66	BM#4 REF INT								
67	BM#1 REF %GOOD								
68	BM#2 REF %GOOD								
69	BM#3 REF %GOOD								
70	BM#4 REF %GOOD								
71	BT MAX. DEPTH {BX}								LSB
72									MSB

BYTE	BIT POSITIONS 7/S	6	5	4	3	2	1	0	
73	BM#1 RSSI AMP								
74	BM#2 RSSI AMP								
75	BM#3 RSSI AMP								
76	BM#4 RSSI AMP								
77	GAIN								
78	(*SEE BYTE 17)								MSB
79	(*SEE BYTE 19)								MSB
80	(*SEE BYTE 21)								MSB
81	(*SEE BYTE 23)								MSB
82	RESERVED								
83									
84									
85									

Figure 13. Bottom-Track Data Format

This data is output only if the BP command is > 0 and PD0 is selected. See Table 39 for a description of the fields.

The PD0 output data format assumes that the instrument is stationary and the bottom is moving. DVL (Speed Log) output data formats (see Special Output Data Formats) assume that the bottom is stationary and that the ADCP or vessel is moving.

Bottom Track is a feature upgrade for WorkHorse ADCP Monitor and Sentinel ADCPs (see Feature Upgrades).

Bottom Track is not available for Long Ranger ADCPs.

This data is output only if the BP command is greater than zero and PD0 is selected. The LSB is always sent first.

Table 39: Bottom-Track Data Format

Hex Digit	Binary Byte	Field	Description
1-4	1,2	ID Code	Stores the bottom-track data identification word (00 06h).
5-8	3,4	BP/BT Pings per ensemble	Stores the number of bottom-track pings to average together in each ensemble (BP command). If BP = 0, the ADCP does not collect bottom-track data. The ADCP automatically extends the ensemble interval (TE) if BP x TP > TE. Scaling: LSD = 1 ping; Range = 0 to 999 pings
9-12	5,6	BD/BT delay before reacquire	Stores the number of ADCP ensembles to wait after losing the bottom before trying to reacquire it (BD command). Scaling: LSD = 1 ensemble; Range = 0 to 999 ensembles
13,14	7	BC/BT Corr Mag Min	Stores the minimum correlation magnitude value (BC command). Scaling: LSD = 1 count; Range = 0 to 255 counts
15,16	8	BA/BT Eval Amp Min	Stores the minimum evaluation amplitude value (BA command). Scaling: LSD = 1 count; Range = 1 to 255 counts
17,18	9	BG/BT %Gd Minimum	Stores the minimum percentage of bottom-track pings in an ensemble that must be good to output velocity data (BG command).
19,20	10	BM/BT Mode	Stores the bottom-tracking mode (BM command). When the Lowered ADCP mode is set (WM15) the Bottom-Track mode will show up as Mode 11 (BM11). When the system uses standard Bottom-Track (BT-RA, see OL command), the Bottom-Track mode will show up as Mode 50 (BM50).
21-24	11,12	BE/BT Err Vel Max	Stores the error velocity maximum value (BE command). Scaling: LSD = 1 mm/s; Range = 0 to 5000 mm/s (0 = did not screen data)
25-32	13–16	Reserved	Reserved
33-48	17-24	BT Range/Beam #1-4 BT Range	Contains the two lower bytes of the vertical range from the ADCP to the sea bottom (or surface) as determined by each beam. This vertical range does not consider the effects of pitch and roll. When bottom detections are bad, BT Range = 0. See bytes 78 through 81 for MSB description and scaling. Scaling: LSD = 1 cm; Range = 0 to 65535 cm
49-64	25-32	BT Velocity/Beam #1-4 BT Vel	The meaning of the velocity depends on the EX (coordinate system) command setting. The four velocities are as follows: a) Beam Coordinates: Beam 1, Beam 2, Beam 3, Beam 4 b) Instrument Coordinates: 1->2, 4->3, toward face, error c) Ship Coordinates: Starboard, Fwd, Upward, Error d) Earth Coordinates: East, North, Upward, Error
65-72	33-36	BTCM/Beam #1-4 BT Corr.	Contains the correlation magnitude in relation to the sea bottom (or surface) as determined by each beam. Bottom-track correlation magnitudes have the same format and scale factor as water-profiling magnitudes (Table 5).
73-80	37-40	BTEA/Beam #1-4 BT Eval Amp	Contains the evaluation amplitude of the matching filter used in determining the strength of the bottom echo. Scaling: LSD = 1 count; Range = 0 to 255 counts
81-88	41-44	BTPG/Beam #1-4 BT %Good	Contains bottom-track percent-good data for each beam, which indicate the reliability of bottom-track data. It is the percentage of bottom-track pings that have passed the ADCP's bottom-track validity algorithm during an ensemble. Scaling: LSD = 1 percent; Range = 0 to 100 percent

Table 39: Bottom-Track Data Format

Hex Digit	Binary Byte	Field	Description
89-92 93-96 97 – 100	45,46 47,48 49,50	Ref Layer (Min, Near, Far)	Stores the minimum layer size, the near boundary, and the far boundary of the BT water-reference layer (BL command). Scaling (minimum layer size): LSD = 1 dm; Range = 0-999 dm Scaling (near/far boundaries): LSD = 1 dm; Range = 0-9999 dm
101- 116	51-58	Ref Vel/Beam #1-4 Ref Layer Vel	Contains velocity data for the water reference layer for each beam. Reference layer velocities have the same format and scale factor as water-profiling velocities (Table 34). The BL command explains the water reference layer.
117- 124	59-62	RLCM/Bm #1-4 Ref Corr	Contains correlation magnitude data for the water reference layer for each beam. Reference layer correlation magnitudes have the same format and scale factor as water-profiling magnitudes (Table 5).
125- 132	63-66	RLEI/Bm #1-4 Ref Int	Contains echo intensity data for the reference layer for each beam. Reference layer intensities have the same format and scale factor as water-profiling intensities.
133- 140	67-70	RLPG/Bm #1-4 Ref %Good	Contains percent-good data for the water reference layer for each beam. They indicate the reliability of reference layer data. It is the percentage of bottom-track pings that have passed a reference layer validity algorithm during an ensemble. Scaling: LSD = 1 percent; Range = 0 to 100 percent
141- 144	71,72	BX/BT Max. Depth	Stores the maximum tracking depth value (BX command). Scaling: LSD = 1 decimeter; Range = 80 to 9999 decimeters
145-152	73-76	RSSI/Bm #1-4 RSSI Amp	Contains the Receiver Signal Strength Indicator (RSSI) value in the center of the bottom echo as determined by each beam. Scaling: LSD ≈ 0.45 dB per count; Range = 0 to 255 counts
153, 154	77	GAIN	Contains the Gain level for shallow water. See WJ command.
155-162	78-81	BT Range MSB/Bm #1-4	Contains the most significant byte of the vertical range from the ADCP to the sea bottom (or surface) as determined by each beam. This vertical range does not consider the effects of pitch and roll. When bottom detections are bad, BT Range=0. See bytes 17 through 24 for LSB description and scaling. Scaling: LSD = 65,536 cm, Range = 65,536 to 16,777,215 cm
163-170	82-85	Reserved	Reserved

Reserved BIT Data Format

BYTE	BIT POSITIONS 7	6	5	4	3	2	1	0	
1	RESERVED FOR TRDI USE								LSB
2									MSB

Figure 14. Reserved BIT Data Format

The data is always output. See Table 40 for a description of the fields.

Table 40: Reserved for TRDI Format

Hex Digit	Binary Byte	Field	Description
1-4	1,2	Reserved for TRDI's use	This field is for TRDI (internal use only).

Checksum Data Format

BYTE	BIT POSITIONS 7	6	5	4	3	2	1	0	
1	CHECKSUM DATA								LSB
2									MSB

Figure 15. Checksum Data Format

The data is always output. See Table 41 for a description of the fields.

Table 41: Checksum Data Format

Hex Digit	Binary Byte	Field	Description
1-4	1,2	Checksum Data	This field contains a modulo 65535 checksum. The WorkHorse ADCP computes the checksum by summing all the bytes in the output buffer excluding the checksum.