LB150 WeatherStation Technical Manual

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- DRAFT -

This document is PRELIMINARY and Subject to Change.

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1. Introduction

This document is a supplement to the Airmar LB150 WeatherStation Owner's Guide.

The LB150 WeatherStation is a multifunctional device that integrates several sensors into a single compact housing. These sensors include:

- Ultrasonic anemometer, providing apparent wind speed and direction
- Thermistor, providing air temperature
- Capacitive humidity sensor, providing % relative humidity
- Piezoresistive pressure sensor, providing barometric pressure
- Magnetoinductive XY sensors, providing magnetic compass heading
- 3-axis MEMS[1] accelerometer, providing pitch and roll angles
- Global Positioning System (GPS) receiver, providing position, and speed and course over ground

In addition to the above directly measured parameters, the LB150 WeatherStation is able to calculate the following values as well, if the necessary data are available:

- True wind speed and direction
- Heading relative to true north
- Dew point
- Apparent wind chill temperature
- True wind chill temperature
- True wind speed relative to water (with optional Airmar® Smart™ speed sensor, not included)

The LB150 WeatherStation provides one communication interface compliant with the NMEA 0183 protocol

This document provides detailed descriptions of the communications protocol for the NMEA 0183 interface used by the LB150 WeatherStation.

For further information about the NMEA 0183 protocol, refer to the document, *NMEA 0183 Standard for Interfacing Marine Electronic Devices, v3.01*. This document is available from the National Marine Electronics Association (www.nmea.org).

[1] MEMS is an acronym for Micro Electro-Mechanical Systems

2. NMEA 0183 Interfaces

The Airmar LB150 WeatherStation has a single standard NMEA 0183-compliant output channel, and a single standard NMEA 0183-compliant input channel. The unit transmits standard NMEA 0183 sentences on its output channel. It also recognizes standard and proprietary NMEA 0183 sentences received on its input channel. The standard baud rate for both input and output channels is 4800 baud, though if desired this may be increased to 38400 baud via a proprietary command.[1]

The transmitted NMEA 0183 sentences are described in section 2.1. Received NMEA 0183 sentences and proprietary commands are described in section 2.2.

2.1. Transmitted NMEA 0183 Sentences

By default, only certain NMEA sentences are enabled for transmission. Other sentences may be enabled individually for transmission via commands sent to the input channel.[2]

The standard transmission interval for most of the transmitted sentences is once per second. However, in models that include an integrated GPS, if every sentence were enabled for transmission, there would not be enough bandwidth in the output channel at 4800 baud to output all sentences within a one second timeframe. Therefore, one or more of the following remedies should be employed:

- To conserve bandwidth, only enable for transmission those sentences required for the given application, and disable all others.
- Reduce the frequency of transmission for less critical sentences.
- Increase the overall bandwidth eightfold by increasing the baud rate from the standard 4800 baud to 38400 baud (though keep in mind that most NMEA 0183 instruments are not capable of operating at 38400 baud)

All NMEA sentences transmitted by the LB150 WeatherStation include a checksum at the end of the sentence, consisting of an asterisk (*) followed by two ASCII hexadecimal characters. In the detailed specifications to follow, these hexadecimal characters are designated by "`hh`".

The standard NMEA 0183 sentences provided by the LB150 WeatherStation are summarized in Table 1. Each of the transmitted sentences in Table 1 is described in detail on the subsequent pages.

[1] See the `$PAMTC,BAUD` command.
[2] See the `$PAMTC,EN` command.

The Maximum Length (chars) column in the table indicates an expected worst-case scenario that can be used for bandwidth budgeting. The total time in seconds required to transmit all enabled sentences in a single interval is

$$Total\_transmission\_time = \frac{Total\_number\_of\_characters \times 10}{baud\_rate}$$

Table 1: NMEA 0183 Regularly Transmitted Sentences

Sentence	Description	Enabled by Default	Maximum Length (chars)
\$GP**DTM**	Datum Reference	No	47
\$GP**GGA**	GPS Fix Data	✓	82
\$GP**GLL**	Geographic Position – Latitude/Longitude	No	48
\$GP**GSA**	GNSS DOP and Active Satellites	No	66
\$GP**GSV**	GNSS Satellites in View	No	70
\$HC**HDG**	Heading, Deviation and Variation	No	33
\$HC**HDT**	Heading relative to True North	✓	19
\$WI**MDA**	Meteorological Composite. Barometric pressure, air temperature, relative humidity, dew point, wind direction, wind speed	✓	81
\$WI**MWD**	Wind Direction and Speed, with respect to north[1]	No	41
\$WI**MWV** (relative)	Wind Speed and Angle, in relation to the centerline of the front of the vehicle (relative)	✓	28
\$WI**MWV** (theoretical)	Wind Speed and Angle, in relation to the centerline of the front of the vehicle (theoretical) [1]	No	28
\$GP**RMC**	Recommended Minimum Specific GNSS Data	No	74
\$GP**VTG**	Course Over Ground and Ground Speed	✓	42
\$WI**VWR**	Relative Wind Speed and Angle	No	41
\$WI**VWT**	True Wind Speed and Angle	No [2]	41
\$YX**XDR** (type A)	Transducer Measurements: wind chill, heat index, and station pressure	✓	74
\$YX**XDR** (type B)	Transducer Measurements: vehicle/instrument attitude (pitch and roll)	✓	43
\$GP**ZDA**	Time and Date	✓	38

[1] True wind data is provided in the \$WIMWD and \$WIMWV (theoretical) sentences if SOG/COG, heading, and magnetic variation data are available from the internal GPS and compass.

[2] \$WIVWT True Wind Speed and Angle referenced to water is provided only if water referenced speed is available via the NMEA 0183 input from an Airmar® Smart™ speed sensor.

$GPDTM

Summary

NMEA 0183 standard Datum Reference.

Syntax

`$GPDTM,<1>,<2>,<3>,<4>,<5>,<6>,<7>,<8>*hh<CR><LF>`

Fields

<1> Three character alphabetical code for local datum:
W84 (WGS84)
W72 (WGS72)
S85 (SGS85)
P90 (PE90)
or IHO datum code from the International Hydrographic Organization Publication S-60 Appendices B and C.

<2> One character subdivision datum code when available, as defined in IHO Publication S-60 Appendices B and C.

<3> Latitude offset, to the nearest .0001 minute

<4> N if field <3> is North Latitude
S if field <3> is South Latitude

<5> Longitude offset, to the nearest .0001 minute

<6> E if field <5> is East Longitude
W if field <5> is West Longitude

<7> Signed altitude offset, to the nearest meter

<8> 3-character reference datum code:
W84 = WGS-84

Default State

Disabled. Transmitted once per second when enabled.

Notes

This sentence may be enabled or disabled via the $PAMTC,EN,DTM command.

Latitude and longitude offsets are positive numbers; the altitude offset may be negative. Offsets change with position; position in the local datum is offset from the position in the reference datum in the directions indicated:

$$P_{local\ datum} = P_{ref\ datum} + offset$$

KGS, OHI-A, OHI-B, OHI-C, OHI-D, OHI-M, SIR, P90, and S85 are not currently supported by the GPS Engine used in the LB150, and therefore are not available for use as Local Datum.

$GPGGA

Summary

NMEA 0183 standard GPS Fix Data.

Syntax

```
$GPGGA,<1>,<2>,<3>,<4>,<5>,<6>,<7>,<8>,
<9>,<10>,<11>,<12>,<13>,<14>*hh<CR><LF>
```

Fields

<1>	UTC of position, in the form hhmmss
<2>	Latitude, to the nearest .0001 minute
<3>	N if field <2> is North Latitude S if field <2> is South Latitude
<4>	Longitude, to the nearest .0001 minute
<5>	E if field <4> is East Longitude W if field <4> is West Longitude
<6>	GPS quality indicator: 0 = Fix not available or invalid 1 = GPS SPS Mode, fix valid 2 = Differential GPS, SPS Mode, fix valid 3 = GPS PPS Mode, fix valid 4 = Real Time Kinematic (RTK) 5 = Float RTK 6 = Estimated (dead reckoning) Mode 7 = Manual Input Mode 8 = Simulator Mode When providing data from the LB150 WeatherStation's internal GPS, the only valid values for the GPS quality indicator are 0, 1, and 2.
<7>	Number of satellites in use, 0-12
<8>	Horizontal dilution of precision (HDOP)
<9>	Altitude relative to mean-sea-level (geoid), meters (to the nearest whole meter)
<10>	M
<11>	Geoidal separation, meters (to the nearest whole meter). This field is not provided by the LB150 WeatherStation, and appears as a null field.

<12> M. This field is not provided by the LB150 WeatherStation, and appears as a null field.

<13> Age of Differential GPS data, seconds. This field is not provided by the LB150 WeatherStation, and appears as a null field.

<14> Differential reference station ID, 0000-1023. This field is not provided by the LB150 WeatherStation, and appears as a null field.

Default State

Enabled. Transmitted once per second.

Notes

This sentence may be enabled or disabled via the $PAMTC,EN,GGA command.

$GPGLL

Summary

NMEA 0183 standard Geographic Position – Latitude/Longitude.

Syntax

`$GPGLL,<1>,<2>,<3>,<4>,<5>,<6>,<7>*hh<CR><LF>`

Fields

<1>	Latitude, to the nearest .0001 minute
<2>	N if field <1> is North Latitude S if field <1> is South Latitude
<3>	Longitude, to the nearest .0001 minute
<4>	E if field <3> is East Longitude W if field <3> is West Longitude
<5>	UTC of position, in the form hhmmss
<6>	Status: A = data valid; V = data invalid
<7>	Mode indicator: A = Autonomous mode D = Differential mode E = Estimated (dead reckoning) mode M = Manual input mode S = Simulator mode N = Data not valid The only values transmitted by the LB150 WeatherStation for the Mode indicator are A, D, and N.

Default State

Disabled. Transmitted once per second when enabled.

Notes

This sentence may be enabled via the $PAMTC,EN,GLL command.

$GPGSA

Summary

NMEA 0183 standard GNSS DOP and Active Satellites.

Syntax

```
$GPGSA,<1>,<2>,<3>,<4>,<5>,<6>,<7>,<8>,<9>,<10>,<11>,
<12>,<13>,<14>,<15>,<16>,<17>*hh<CR><LF>
```

Fields

<1>	M = Manual, forced to operate in 2D or 3D mode A = Automatic, allowed to automatically switch 2D/3D
<2>	1 = Fix not available 2 = 2D fix 3 = 3D fix
<3>-<14>	ID numbers of satellites used in solution
<15>	Positional Dilution of Precision (PDOP). This field is null unless the GPS has a 3D fix.
<16>	Horizontal Dilution of Precision (HDOP). This field is null unless the GPS has either a 2D fix or a 3D fix.
<17>	Vertical Dilution of Precision (VDOP). This field is null unless the GPS has a 3D fix.

Default State

Disabled. Transmitted once per second when enabled.

Notes

This sentence may be enabled via the $PAMTC,EN,GSA command.

$GPGSV

Summary

NMEA 0183 standard GNSS Satellites in View.

Syntax

```
$GPGSV,<1>,<2>,<3>,<4>,<5>,<6>,<7>,<8>,<9>,<10>,<11>,
<12>,<13>,<14>,<15>,<16>,<17>,<18>,<19>*hh<CR><LF>
```

Fields

<1>	Total number of GSV sentences (1 to 3 for internal GPS in LB150 WeatherStation)
<2>	Sentence number (1, 2, or 3)
<3>	Total number of satellites in view
<4>	Satellite ID number, 1st SV
<5>	Elevation degrees, 0 to 90, to the nearest degree, 1st SV
<6>	Azimuth, degrees True, to the nearest degree, 1st SV
<7>	SNR (C/No) 00-99 dB-Hz, 1st SV (null field if satellite not tracked)
<8>	Satellite ID number, 2nd SV
<9>	Elevation degrees, 0 to 90, to the nearest degree, 2nd SV
<10>	Azimuth, degrees True, to the nearest degree, 2nd SV
<11>	SNR (C/No) 00-99 dB-Hz, 2nd SV (null field if satellite not tracked)
<12>	Satellite ID number, 3rd SV
<13>	Elevation degrees, 0 to 90, to the nearest degree, 3rd SV
<14>	Azimuth, degrees True, to the nearest degree, 3rd SV
<15>	SNR (C/No) 00-99 dB-Hz, 3rd SV (null field if satellite not tracked)
<16>	Satellite ID number, 4th SV
<17>	Elevation degrees, 0 to 90, to the nearest degree, 4th SV
<18>	Azimuth, degrees True, to the nearest degree, 4th SV
<19>	SNR (C/No) 00-99 dB-Hz, 4th SV (null field if satellite not tracked)

Default State

Disabled. Transmitted once per second when enabled. This sentence is transmitted in groups of up to three instances, containing data for up to 4 satellites with each instance, for a total of up to 12 satellites. Fields <1> and <3> only contain data in the first instance; they are null fields in the second and third instances.

Notes

This sentence may be enabled via the $PAMTC,EN,GSV command.

$HC**HDG**

Summary

NMEA 0183 standard Heading, Deviation and Variation.

Syntax

`$HCHDG,<1>,<2>,<3>,<4>,<5>*hh<CR><LF>`

Fields

`<1>`	Magnetic sensor heading, degrees, to the nearest 0.1 degree.
`<2>`	Magnetic deviation, degrees east or west, to the nearest 0.1 degree.
`<3>`	E if field <2> is degrees East W if field <2> is degrees West
`<4>`	Magnetic variation, degrees east or west, to the nearest 0.1 degree.
`<5>`	E if field <4> is degrees East W if field <4> is degrees West

Default State

Disabled. Transmitted twice per second when enabled.

Notes

This sentence may be enabled or disabled via the $PAMTC,EN,HDG command.

$HC**HDT**

Summary

NMEA 0183 standard Heading relative to True North

Syntax

`$HCHDT,<1>,<2>*hh<CR><LF>`

Fields

`<1>`	Heading relative to True North
`<2>`	T = True

Default State

Enabled. Transmitted twice per second.

Notes

This sentence may be enabled or disabled via the $PAMTC,EN,HDT command.

The data in field <1> is only provided if both magnetic compass heading and magnetic variation values are available.

$WI**MDA**

Summary

NMEA 0183 standard Meteorological Composite.

Syntax

```
$WIMDA,<1>,<2>,<3>,<4>,<5>,<6>,<7>,<8>,<9>,<10>,<11>,
<12>,<13>,<14>,<15>,<16>,<17>,<18>,<19>,<20>*hh
<CR><LF>
```

Fields

<1>	Barometric pressure, inches of mercury, to the nearest 0.01 inch
<2>	I = inches of mercury
<3>	Barometric pressure, bars, to the nearest .001 bar
<4>	B = bars
<5>	Air temperature, degrees C, to the nearest 0.1 degree C
<6>	C = degrees C
<7>	Water temperature, degrees C (this field left blank by WeatherStation)
<8>	C = degrees C (this field left blank by WeatherStation)
<9>	Relative humidity, percent, to the nearest 0.1 percent
<10>	Absolute humidity, percent (this field left blank by WeatherStation)
<11>	Dew point, degrees C, to the nearest 0.1 degree C
<12>	C = degrees C
<13>	Wind direction, degrees True, to the nearest 0.1 degree
<14>	T = true
<15>	Wind direction, degrees Magnetic, to the nearest 0.1 degree
<16>	M = magnetic
<17>	Wind speed, knots, to the nearest 0.1 knot
<18>	N = knots
<19>	Wind speed, meters per second, to the nearest 0.1 m/s
<20>	M = meters per second

Default State

Enabled. Transmitted once per second.

Notes

This sentence may be enabled or disabled via the $PAMTC,EN,MDA command.

The barometric pressure provided in this sentence is the *altimeter setting*, which is the barometric pressure corrected for altitude above sea level. See the transmitted $YXXDR(A) sentence, and the received $PAMTC,ALT command, for further information.

$WI**MWD**

Summary

NMEA 0183 standard Wind Direction and Speed, with respect to north.

Syntax

`$WIMWD,<1>,<2>,<3>,<4>,<5>,<6>,<7>,<8>*hh<CR><LF>`

Fields

<1>	Wind direction, 0.0 to 359.9 degrees True, to the nearest 0.1 degree
<2>	T = True
<3>	Wind direction, 0.0 to 359.9 degrees Magnetic, to the nearest 0.1 degree
<4>	M = Magnetic
<5>	Wind speed, knots, to the nearest 0.1 knot.
<6>	N = Knots
<7>	Wind speed, meters/second, to the nearest 0.1 m/s.
<8>	M = Meters/second

Default State

Disabled. Transmitted once per second when enabled.

Notes

The wind speed and direction data provided in this sentence are calculated using vector math based on the measured apparent wind speed and direction, SOG and COG from the GPS, compass heading, and magnetic variation. If any of these data are not available, this sentence shall be transmitted with null fields.

This sentence may be enabled or disabled via the $PAMTC,EN,MWD command.

$WIMWV

Summary

NMEA 0183 standard Wind Speed and Angle, in relation to the centerline of the front of the vehicle.

Syntax

`$WIMWV,<1>,<2>,<3>,<4>,<5>*hh<CR><LF>`

Fields

`<1>` Wind angle, 0.0 to 359.9 degrees, in relation to the centerline of the front of the vehicle, to the nearest 0.1 degree. If the data for this field is not valid, the field will be blank.

`<2>` Reference:

R = Relative (apparent wind, as felt when standing on the moving vehicle)
T = Theoretical (calculated actual wind, as though the vehicle were stationary)

`<3>` Wind speed, to the nearest tenth of a unit. If the data for this field is not valid, the field will be blank.

`<4>` Wind speed units:

K = km/hr
M = m/s
N = knots
S = statute miles/hr

In the LB150 WeatherStation, this field always contains "N" (knots).

`<5>` Status:

A = data valid; V = data invalid

Default State

MWV(R): Enabled. Transmitted twice per second.
MWV(T): Disabled. Transmitted once per second when enabled.

Notes

Depending on the contents of the Reference field (field <2>), this sentence provides either relative (apparent) wind or theoretical (true) wind data, both in relation to the front of the vehicle. Although it is conceivable that both of these forms could be useful simultaneously, the LB150 WeatherStation by default only outputs this sentence once in the MWV(R) form.

To enable/disable the theoretical (true) form of this sentence, use the $PAMTC,EN,MWVT command. To enable/disable the relative (apparent) form, use the $PAMTC,EN,MWVR command.

$GP**RMC**

Summary

NMEA 0183 standard Recommended Minimum Specific GNSS Data.

Syntax

```
$GPRMC,<1>,<2>,<3>,<4>,<5>,<6>,<7>,<8>,
<9>,<10>,<11>,<12>*hh<CR><LF>
```

Fields

<1>	UTC of position, in the form hhmmss
<2>	Status: A = Data Valid; V = Navigation Receiver Warning
<3>	Latitude, to the nearest .0001 minute
<4>	N if field <2> is North Latitude S if field <2> is South Latitude
<5>	Longitude, to the nearest .0001 minute
<6>	E if field <4> is East Longitude W if field <4> is West Longitude
<7>	Speed Over Ground, knots, to the nearest 0.1 knot
<8>	Course Over Ground, degrees True, to the nearest 0.1 degree
<9>	Date: ddmmyy
<10>	Magnetic Variation, degrees E/W, to the nearest 0.1 degree
<11>	E if field <10> is degrees East W if field <10> is degrees West
<12>	Mode indicator: A = Autonomous mode D = Differential mode E = Estimated (dead reckoning) mode M = Manual input mode S = Simulator mode N = Data not valid The only values transmitted by the LB150 WeatherStation for the Mode indicator are A, D, and N.

Default State

Disabled. Transmitted once per second when enabled.

Notes

This sentence may be enabled via the $PAMTC,EN,RMC command.

$GPVTG

Summary

NMEA 0183 standard Course Over Ground and Ground Speed.

Syntax

`$GPVTG,<1>,<2>,<3>,<4>,<5>,<6>,<7>,<8>,<9>*hh<CR><LF>`

Fields

<1>	Course Over Ground, degrees True, to the nearest 0.1 degree
<2>	T = True
<3>	Course Over Ground, degrees Magnetic, to the nearest 0.1 degree
<4>	M = Magnetic
<5>	Speed Over Ground, knots, to the nearest 0.1 knot
<6>	N = Knots
<7>	Speed Over Ground, km/hr, to the nearest 0.1 km/hr
<8>	K = km/hr
<9>	Mode indicator: A = Autonomous mode D = Differential mode E = Estimated (dead reckoning) mode M = Manual input mode S = Simulator mode N = Data not valid The only values transmitted by the LB150 WeatherStation for the Mode indicator are A, D, and N.

Default State

Enabled. Transmitted once per second.

Notes

This sentence may be enabled or disabled via the $PAMTC,EN,VTG command.

$WIVWR

Summary

NMEA 0183 Relative (Apparent) Wind Speed and Angle. For vehicle mounted instruments, wind angle is in relation to the vehicle's heading, and wind speed measured relative to the moving vehicle. For stationary instruments, wind speed and angle are relative to the sensor.

Syntax

`$WIVWR,<1>,<2>,<3>,<4>,<5>,<6>,<7>,<8>*hh<CR><LF>`

Fields

<1>	Measured wind angle relative to the vehicle, 0 to 180°, left/right of vehicle heading, to the nearest 0.1 degree
<2>	L = left, or R = right
<3>	Measured wind speed, knots, to the nearest 0.1 knot
<4>	N = knots
<5>	Wind speed, meters per second, to the nearest 0.1 m/s
<6>	M = meters per second
<7>	Wind speed, km/h, to the nearest km/h
<8>	K = km/h

Default State

Disabled. Transmitted once per second if enabled.

Notes

This sentence may be enabled via the $PAMTC,EN,VWR command.

$WIVWT

Summary

NMEA 0183 True wind angle in relation to the vessel's heading, and true wind speed referenced to the water. True wind is the vector sum of the Relative (apparent) wind vector and the vessel's velocity vector relative to the water along the heading line of the vessel. It represents the wind at the vessel if it were stationary relative to the water and heading in the same direction. Since LB150s are not intended for use on boats, this sentence is not likely to be useful, but if enabled and VHW sentence is received, it will work.

Syntax

`$WIVWT,<1>,<2>,<3>,<4>,<5>,<6>,<7>,<8>*hh<CR><LF>`

Fields

<1>	Calculated wind angle relative to the vessel, 0 to 180°, left/right of vessel heading, to the nearest 0.1 degree
<2>	L = left, or R = right
<3>	Calculated wind speed, knots, to the nearest 0.1 knot
<4>	N = knots
<5>	Wind speed, meters per second, to the nearest 0.1 m/s
<6>	M = meters per second
<7>	Wind speed, km/h, to the nearest km/h
<8>	K = km/h

Default State

Disabled, but when enabled, automatically prohibited until water speed is provided via the NMEA 0183 input. Transmitted once per second when enabled and not prohibited.

Notes

This sentence can be manually enabled or disabled via the $PAMTC,EN,VWT command.

$YXXDR

Summary

NMEA 0183 Transducer Measurements. Used in the LB150 WeatherStation to provide wind chill, heat index, barometric station pressure, and vehicle attitude (pitch and roll) data. For stationary instruments pitch and roll indicate the orientation in which the instrument was mounted.

IMPORTANT NOTE: See the discussion in the Notes section below regarding the behavior of the XDR sentence with regard to null fields and commas.

Syntax

```
$YXXDR,<1>, <2>, <3>, <4>,
       <5>, <6>, <7>, <8>,
       <9>, <10>,<11>,<12>,
       <13>,<14>,<15>,<16>
       *hh<CR><LF>
```

Fields

There are two versions of this sentence, the "A" version, and the "B" version.

The fields in the A version of the XDR sentence are as follows:

<1>	C = temperature
<2>	Calculated “relative” wind chill temperature, degrees Celsius, to the nearest 0.1 degree
<3>	C = degrees C
<4>	WCHR (ID indicating relative wind chill)
<5>	C = temperature
<6>	Calculated “theoretical” wind chill temperature, degrees Celsius, to the nearest 0.1 degree
<7>	C = degrees C
<8>	WCHT (ID indicating theoretical wind chill)
<9>	C = temperature
<10>	Calculated heat index, degrees Celsius, to the nearest 0.1 degree
<11>	C = degrees C
<12>	HINX (ID indicating heat index)

<13> P = pressure

<14> Actual measured barometric pressure, or "station pressure", bars, to the nearest 0.001 bar

<15> B = bars

<16> STNP (ID indicating station pressure)

The fields in the B version of the XDR sentence are as follows:

<1> A = angular displacement

<2> Pitch: oscillation of vehicle about its latitudinal axis. Front of the vehicle moving up is positive. Value reported to the nearest 0.1 degree.

<3> D = degrees

<4> PTCH (ID indicating pitch of vehicle)

<5> A = angular displacement

<6> Roll: oscillation of vehicle about its longitudinal axis. Roll to the right is positive. Value reported to the nearest 0.1 degree.

<7> D = degrees

<8> ROLL (ID indicating roll of vehicle)

<9> Not used

<10> Not used

<11> Not used

<12> Not used

<13> Not used

<14> Not used

<15> Not used

<16> Not used

Default State

$YXXDR(A): Disabled. Transmitted once per second when enabled.
$YXXDR(B): Disabled. Transmitted once per second when enabled.

Notes

The fields in an XDR sentence are grouped in sets of four. There may be up to four sets, with four fields per set, in a single transmitted XDR sentence. Each set contains, in order, the four fields <Type>, <Data>, <Units>, and <ID>. If for

some reason the contents of a given set are not available, then the entire set (including commas) may be omitted.

Because there are two versions of the XDR sentence, and because a group of four fields can be omitted entirely, it is necessary when parsing any XDR sentence to examine the <ID> field in each set of four fields in order to identify the meaning of the data in that set.

The XDR(A) sentence may be enabled via the $PAMTC,EN,XDRA command. The XDR(B) sentence may be enabled via the $PAMTC,EN,XDRB command.

The **wind chill temperature** is the perceived temperature on a person's face at the current wind speed. The calculation assumes that the wind speed measured by the sensor is the same as the wind speed at the face of an observer. The "relative" wind chill uses the measured apparent wind speed for this calculation, and the "theoretical" wind chill uses the calculated true wind speed. The wind chill temperature is only defined when the air temperature is below 50°F (10°C) and the wind speed is above 3 mph.

The **heat index** is the apparent temperature felt by a person's skin when exposed to air with a high moisture content. Dry air allows evaporative cooling of the skin's surface. The higher the humidity, the less the skin can cool itself with evaporative cooling. The heat index is only defined when air temperature is above 80°F (27°C) and relative humidity is above 40%.

The barometric **station pressure** is the raw, uncorrected barometric pressure reading. This is provided here in the XDRA sentence, and is distinct from the *altimeter setting*, which is the barometric pressure corrected for altitude, provided in the MDA sentence.

The reported **pitch and roll** values are adjusted by the azimuth, pitch, and roll offsets established with the $PAMTC,ATTOFF command.

$GPZDA

Summary

NMEA 0183 standard Time and Date.

Syntax

`$GPZDA,<1>,<2>,<3>,<4>,<5>,<6>*hh<CR><LF>`

Fields

<1>	UTC time of day, in the form hhmmss
<2>	UTC day, 01 to 31
<3>	UTC month, 01 to 12
<4>	UTC year (four digits, e.g. 2006)
<5>	Local time zone hours, 00 to +/-13 hrs
<6>	Local time zone minutes, 00 to +59

Default State

Enabled. Transmitted once per second.

Notes

This sentence may be enabled or disabled via the $PAMTC,EN,ZDA command.

Local time zone is the magnitude of hours plus the magnitude of minutes added, with the sign of local zone hours, to local time to obtain UTC. Local zone is generally negative for East longitudes with local exceptions near the International Date Line.

Examples:

At Chatham Is. (New Zealand) at 1230 (noon) local time on June 10, 1995:

`$GPZDA,234500,09,06,1995,-12,45*6C<CR><LF>`

In the Cook Islands at 1500 local time on June 10, 1995:

`$GPZDA,013000,11,06,1995,10,30*4A<CR><LF>`

In the LB150, the local time zone is not changeable via the NMEA 0183 interface.

2.2. Received NMEA 0183 Sentences and Commands

The LB150 WeatherStation has an NMEA 0183-compliant input channel that is capable of receiving standard NMEA sentences as well as proprietary commands for initialization, calibration, or to modify the behavior of the unit.

All received sentences and commands can include or omit the NMEA checksum. If a checksum is included, the sentence will be checked against its checksum, and the sentence will be accepted only if there is a checksum match. If the NMEA checksum is excluded, it is required that the preceding asterisk (*) also be excluded. If no checksum is provided, the LB150 WeatherStation will accept the sentence without error checking. It is recommended that all sentences and commands provided to the WeatherStation include a checksum to help ensure integrity of the transmitted data.

The sentences recognized by the LB150 WeatherStation on the serial input channel are summarized in Table 2 on the next page.

Note that the prefix "$--" appearing in the descriptions for several of the listed sentences should be replaced by a "$" followed by the two-character talker ID of the transmitting device.

Each of the sentences in Table 2 is described in detail on the subsequent pages.

2.2.1. Precedence of Data

In a given installation, certain data items might be available from more than one source. In this circumstance, the following precedence rules apply. The calculation of true wind, in particular, depends on these precedence rules.

Heading and Deviation:

$--HDT supersedes $--HDG and the internal compass.
$--HDG supersedes the internal compass
$--VHW (Note: if heading is supplied in this received sentence, it is ignored.)

Table 2: NMEA 0183 Received Sentences and Commands

Sentence or Command	Description
$--HDG	Standard NMEA Heading, Deviation, and Variation
$--HDT	Standard NMEA Heading, True
$--VHW	Standard NMEA Water Speed and Heading (for water speed)
$PAMTC,ALT	Program the LB150 WeatherStation with altitude settings
$PAMTC,ATTOFF	Program the LB150 WeatherStation with angular attitude offsets: azimuth, pitch, and roll
$PAMTC,BAUD	Change the baud rate from the nominal 4800 baud to 38400 baud
$PAMTC,DATUM	Define the local datum to which GPS position locations are referenced
$PAMTC,EN	Enable/disable transmission of specific sentences, and change their rate of transmission
$PAMTC,ERST	Reset the user portion of nonvolatile EEPROM to factory defaults
$PAMTC,HEATER	Control the WeatherStation internal heater.
$PAMTC,OPTION	Enable/disable certain WeatherStation features
$PAMTC,POST	Query Power On Self Test results
$PAMTC,QPS	Query part number and serial number strings
$PAMTC,QV	Query WeatherStation hardware and firmware versions
$PAMTC,RESET	Reset the LB150 WeatherStation
$PAMTC,SIM	Enable/disable Simulate Mode.
$PAMTX	Pause or resume all automatic transmission of messages

NMEA 0183 RECEIVED SENTENCE

$--HDG

Summary

NMEA 0183 standard Heading, Deviation and Variation.

Syntax

`$--HDG,<1>,<2>,<3>,<4>,<5>*hh<CR><LF>`

Fields

<1>	Magnetic sensor heading, degrees.
<2>	Magnetic deviation, degrees east or west.
<3>	E if field <2> is degrees East W if field <2> is degrees West
<4>	Magnetic variation, degrees east or west.
<5>	E if field <4> is degrees East W if field <4> is degrees West

Notes

See section 2.2.1. for precedence rules regarding data received via this sentence.

$--HDT

Summary

NMEA 0183 standard Heading, True.

Syntax

`$--HDT,<1>,<2>*hh<CR><LF>`

Fields

<1>	Magnetic sensor heading, degrees.
<2>	T = True.

Notes

See section 2.2.1. for precedence rules regarding data received via this sentence.

NMEA 0183 RECEIVED SENTENCE

$--VHW

Summary

NMEA 0183 standard Water Speed and Heading.

Syntax

`$--VHW,<1>,<2>,<3>,<4>,<5>,<6>,<7>,<8>*hh<CR><LF>`

Fields

<1>	Compass Heading, degrees True
<2>	T = true
<3>	Compass Heading, degrees Magnetic
<4>	M = magnetic
<5>	Water speed, knots
<6>	N = knots
<7>	Water speed, km/h
<8>	K = km/h

Notes

This sentence is used to obtain water speed from an Airmar® Smart™ speed sensor. The water speed data is used to calculate true wind relative to the water.

The compass heading fields in this sentence are ignored by the LB150 WeatherStation.

See section 2.2.1. for precedence rules regarding data received via this sentence.

NMEA 0183 RECEIVED SENTENCE

$PAMTC

Summary

Prefix for recognized proprietary commands.

Syntax

`$PAMTC,<1>…*hh<CR><LF>`

Fields

`<1>` Command mnemonic. This may be any of the following:

```
ALT
ATTOFF
BAUD
DATUM
EN
ERST
HEATER
OPTION
POST
QPS
QV
RESET
SIM
```

The number and meaning of any subsequent fields is dependent on the command mnemonic. Each of the command mnemonics defines a separate proprietary command (or set of commands) recognized by the LB150 WeatherStation. These commands are each described in their own section on the following pages.

NMEA 0183 RECEIVED SENTENCE

$PAMTC,**ALT**

Summary

Settings related to the altitude of the LB150.

Syntax

One of the following forms:

`$PAMTC,ALT,SET,<2>,<3>,<4>*hh<CR><LF>`

`$PAMTC,ALT,Q*hh<CR><LF>`

Fields

`<2>` Fixed altitude, -999.9 meters to +40,000.0 meters, to the nearest 0.1 meter.

Default value = 0 meters

`<3>` 0 = Do not use fixed altitude for GPS 2D mode
1 = Use fixed altitude for GPS 2D mode

Default value = 0

`<4>` 0 = Do not use altitude for barometric pressure altimeter setting ($WIMDA, fields 1 and 3)

1 = Barometric pressure altimeter setting uses fixed altitude (field <2>).

2 = Barometric pressure altimeter setting uses GPS altitude when GPS has a 3D fix, or fixed altitude (field <2>) when GPS does not have a 3D fix.

Default value = 2.

Notes

The $PAMTC,ALT,SET,<2>,<3>,<4> command is used to program the LB150 WeatherStation with a fixed altitude setting to be used in calculating a more accurate GPS position when the GPS is operating in 2D mode, and in calculating

the barometric pressure altimeter setting provided in fields 1 and 3 of the transmitted $WIMDA sentence.

Fields <3> and<4> of the $PAMTC,ALT,SET command define how to use the altitude setting provided in field <2>.

All of the parameters of the $PAMTC,ALT,SET command are stored in nonvolatile EEPROM memory within the LB150, and so remain programmed even after cycling power. If any of the fields <2>, <3>, or <4> are null fields, the corresponding stored value will remain unchanged.

The $PAMTC,ALT,Q command is used to query the values of the parameters currently programmed into the LB150. The unit will reply with

$PAMTR,ALT,*a,b,c*

where *a, b,* and c correspond to fields <2>, <3>, and <4>, respectively, in the $PAMTC,ALT,SET command.

See also:

NMEA 0183 received proprietary sentence $PAMTC,OPTION, option 2.

NMEA 0183 transmitted sentence $YXXDR (barometric pressure).

NMEA 0183 RECEIVED SENTENCE

$PAMTC,**ATTOFF**

Summary

A set of proprietary commands to set and query the angular attitude offsets for the LB150 WeatherStation when mounted on a vehicle, and not necessary for stationary instruments.

Syntax

One of the following forms:

```
$PAMTC,ATTOFF,SET,<3>,<4>,<5>*hh<CR><LF>
```

```
$PAMTC,ATTOFF,Q*hh<CR><LF>
```

Fields

<3>	Signed azimuth offset (yaw offset), degrees, to the nearest tenth of a degree. The value must be between -180.0 and +180.0 degrees. Negative values indicate the forward mark on the sensor housing is oriented toward the right side of the vehicle; positive values toward the left side.
<4>	Signed pitch offset, degrees, to the nearest tenth of a degree. The value must be between -45.0 and +45.0 degrees. Positive values indicate the sensor is tilted forward toward the front of the vehicle; negative values indicate the sensor is tilted toward the back of the vehicle.
<5>	Signed roll offset, degrees, to the nearest tenth of a degree. The value must be between -45.0 and +45.0 degrees. Positive values indicate the sensor is tilted toward the left side; negative values toward the right side.

Notes

Note that in the NMEA 0183 command, the arguments are in degrees. The values stored in the LB150 are in radians. Therefore, when using the $PAMTC,ATTOFF command, there may be a slight rounding error causing the values read back from the LB150 to be different than the commanded values by one least significant digit.

The $PAMTC,ATTOFF,SET,<3>,<4>,<5> command is used to program the LB150 WeatherStation with the attitude offset angles when the sensor is not oriented parallel to the centerline, and perpendicular to the wheel base of the vehicle. The programmed values are stored in nonvolatile EEPROM memory

within the WeatherStation, and so remain programmed even after cycling power. If any of the fields <3>, <4>, or <5> are null fields, the corresponding stored value will remain unchanged.

The $PAMTC,ATTOFF,Q command is used to query the values of the attitude offset angles currently programmed into the WeatherStation. The unit will reply with

$PAMTR,ATTOFF,*a,b,c*

where *a* is the current signed azimuth offset value, *b* is the current signed pitch offset value, and *c* is the current signed roll offset value. All values are reported to the nearest tenth of a degree.

The factory default value for all three parameters is 0.0 degrees.

The azimuth offset angle is used to adjust the apparent wind angle relative to the front of the vehicle, and the vehicle's heading when using the internal compass. These values are further used in calculating the true wind speed and angle.

The azimuth offset angle, along with the pitch and roll offset angles are also used to adjust the reported pitch and roll values in the transmitted $WIXDR sentence. A properly set azimuth offset angle will allow the unit to accurately report pitch and roll of the vehicle, even though the orientation mark on the sensor housing may not be facing precisely toward the front of the vehicle. The recommended procedure to set these offsets is as follows:

1. If the unit is mounted on a vehicle, this procedure should be performed with the vehicle at rest on level ground.
2. First, zero out all offsets by sending the command $PAMTC,ATTOFF,SET,0,0,0.
3. Determine the desired azimuth offset angle, and program this into the sensor using the command $PAMTC,ATTOFF,SET,*a* where *a* is the azimuth offset of the sensor relative to the front of the vehicle, in degrees. The pitch and roll offset fields should be omitted for this step (or set to zeroes).
4. Allow the vehicle to come to rest in a "level" state, and then read the values of pitch and roll that are reported by the XDR sentence.
5. Program the *negated* versions of these measured pitch and roll values back into the unit with the $PAMTC,ATTOFF,SET,,*b,c* sentence. For example, if the XDR sentence reports an average pitch angle of 6.2 degrees, and an average roll angle of -4.3 degrees, then you would send the sentence $PAMTC,ATTOFF,SET,,-6.2,4.3 to the WeatherStation. Note that the azimuth offset field in this sentence is a null field, indicating we are not changing its value at this time.
6. At this point the transmitted XDR sentences should be producing values that are centered around 0.0 degrees for both pitch and roll.

7. The programmed attitude offset values may be checked at any time by sending the command $PAMTC,ATTOFF,Q to the unit; it will reply with $PAMTR,ATTOFF,*a,b,c*.

NMEA 0183 RECEIVED SENTENCE

$PAMTC,**BAUD**

Summary

Change the baud rate for both the transmitting and receiving NMEA 0183 channels.

Syntax

One of the following forms:

`$PAMTC,BAUD,4800*hh<CR><LF>`

`$PAMTC,BAUD,38400*hh<CR><LF>`

Notes

The $PAMTC,BAUD command may be used to increase the baud rate from the standard 4800 baud to 38400 baud. This will provide an eightfold increase in the bandwidth of the NMEA 0183 interface, allowing more data to be transmitted in a given period of time.

On power up, the NMEA input and output interfaces always default to 4800 baud.

It is recommended to employ the following sequence when changing the baud rate for the WeatherStation from 4800 baud to 38400 baud. The following assumes there is a single host device communicating with the WeatherStation:

1. Send the $PAMTX command to the WeatherStation (at 4800 baud) to temporarily disable transmission of periodic sentences.
2. Send the $PAMTC,BAUD,38400 command (at 4800 baud) to instruct the WeatherStation to change its baud rate to 38400. The unit will finish transmitting any periodic sentences in progress at 4800 baud, and will then change its interface to use 38400 baud.
3. Delay a short interval within the host to allow reception of any remaining queued sentences from the WeatherStation at 4800 baud.
4. Change the baud rate on the host's serial port to 38400 baud.
5. Send the $PAMTX,1 command to the WeatherStation (at 38400 baud) to resume transmission of periodic sentences.
6. All subsequent communication with the WeatherStation will be at 38400 baud, until the unit is powered down or reset, or the $PAMTC,BAUD,4800 command is sent to the unit.

Note that a baud rate of 38400 does not comply with the NMEA 0183 standard.

NMEA 0183 RECEIVED SENTENCE

$PAMTC,**COMP**

Summary

User calibration commands for the internal compass sensor. This can not be used for stationary instruments.

Syntax

One of the following forms:

```
$PAMTC,COMP,GO*hh<CR><LF>
$PAMTC,COMP,RESETALL*hh<CR><LF>
$PAMTC,COMP,RESETCAL*hh<CR><LF>
$PAMTC,COMP,RESETDAMP*hh<CR><LF>
$PAMTC,COMP,SET,<1>,<2>,<3>,<4>,<5>,<6>,<7>,<8>,<9>*hh<CR><LF>
$PAMTC,COMP,Q*hh<CR><LF>
$PAMTC,COMP,X*hh<CR><LF>
$PAMTC,COMP,VERIFY*hh<CR><LF>
```

$PAMTC,COMP,GO

Summary

Initiate a user calibration sequence for the internal compass sensor.

Syntax

`$PAMTC,COMP,GO*hh<CR><LF>`

The user calibration sequence for the LB150 is as follows:

1. The weather station is installed on the vehicle. The unit under test is powered up.
2. The `$PAMTC,COMP,GO*hh<CR><LF>` command is sent to the weather station's NMEA 0183 input channel to initiate user calibration mode.
3. During the user calibration process, the vehicle is rotated slowly (driven in a circle) and the sensor calculates the resulting coefficients. Once the weather station has determined that enough data has been collected for the purpose of calculating the coefficients, it transmits the following sentence:
   `$PAMTR,COMP,XXXX,`
   `<1>,<2>,<3>,<4>,<5>,<6>,<7>,<8>,<9>*hh<CR><LF>`. Where XXXX is "PASS" or "FAIL".
4. If PASS was transmitted, then the offsets that are now in use and saved in EEPROM are the newly calculated ones.

Reply

The weather station will reply immediately with:
`$PAMTR,COMP,INPROCESS,`
`<1>,<2>,<3>,<4>,<5>,<6>,<7>,<8>,<9>*hh<CR><LF>`

Where fields <1> through <9> contain the data from the weather station's nonvolatile EEPROM, as defined in the "Q", Query Command.

Upon successful completion the weather station will reply with:
`$PAMTR,COMP,PASS,`
`<1>,<2>,<3>,<4>,<5>,<6>,<7>,<8>,<9>*hh<CR><LF>`

Or, upon failure it will reply with:
`$PAMTR,COMP,FAILx,`
`<1>,<2>,<3>,<4>,<5>,<6>,<7>,<8>,<9>*hh<CR><LF>`

Where x indicates the type of failure, 1 = Timeout, 2 = Tilt Error, or 3 = Other Error.

$PAMTC,COMP,RESETALL

Summary

Reset the user calibration coefficients and damping control to the default values.

Syntax

```
$PAMTC,COMP,RESETALL*hh<CR><LF>
```

Reply

The weather station will reset the user calibration coefficients and damping control (fields 1-9) and reply with:

```
$PAMTR,COMP,RESETALL,
<1>,<2>,<3>,<4>,<5>,<6>,<7>,<8>,<9>*hh<CR><LF>
```

where fields <1> through <9> contain the data from the weather station's nonvolatile EEPROM, as defined in the "Q", Query Command.

$PAMTC,COMP,RESETCAL

Summary

Reset the user calibration coefficients to the default values.

Syntax

```
$PAMTC,COMP,RESETCAL*hh<CR><LF>
```

Reply

The weather station will reset the user calibration coefficients (fields 1 – 6) and reply with:

```
$PAMTR,COMP,RESETCAL,
<1>,<2>,<3>,<4>,<5>,<6>,<7>,<8>,<9>*hh<CR><LF>
```

where fields <1> through <9> contain the data from the weather station's nonvolatile EEPROM, as defined in the "Q", Query Command.

$PAMTC,COMP,RESETDAMP

Summary

Reset the user damping control to the default values.

Syntax

```
$PAMTC,COMP,RESETDAMP*hh<CR><LF>
```

Reply

The weather station will reset the user damping control (fields 7-9) and reply with:

```
$PAMTR,COMP,RESETDAMP,
<1>,<2>,<3>,<4>,<5>,<6>,<7>,<8>,<9>*hh<CR><LF>
```

where fields <1> through <9> contain the data from the weather station's nonvolatile EEPROM, as defined in the "Q", Query Command.

$PAMTC,COMP,SET

Summary

Set one or more user compass calibration coefficients.

Syntax

```
$PAMTC,COMP,SET,<1>,<2>,<3>,<4>,<5>,<6>,<7>,<8>,<9>*hh
<CR><LF>
```

where fields <1> through <9> contain the data to be set into the weather station's nonvolatile EEPROM corresponding to the fields as follows.

All fields are 16-bit signed fixed point decimal integers.

<1> X axis Gain value, hundredths used as multiplier.

<2> Y axis Gain value, hundredths used as multiplier.

<3> Z axis Gain value, hundredths used as multiplier.

<4> X axis linear offset, hundredths of micro-Teslas.

<5> Y axis linear offset, hundredths of micro-Teslas.

<6> Z axis linear offset, hundredths of micro-Teslas.

<7> X axis angular offset, tenths of degrees.

<8> Pitch and Roll Damping, twentieths of a second.

<9> Compass/RateGyro Damping, twentieths of a second.

Notes

Currently only Linear Offsets (X and Y) and Damping values are supported.
Valid ranges for data:
Gain: 50 to 500
Linear Offset: -32000 to +32000
X-Angular Offset: 0 to 3600
Pitch and Roll Damping: 0 to 200
Compass/RateGyro Damping: 0 to 2400

$PAMTC,COMP,Q

Summary

Query the weather station for the stored user compass calibration coefficients.

Syntax

`$PAMTC,COMP,Q*hh<CR><LF>`

Reply

The weather station will reply with:

```
$PAMTR,COMP,Q,
<1>,<2>,<3>,<4>,<5>,<6>,<7>,<8>,<9>*hh<CR><LF>
```

where fields <1> through <9> contain the data from the weather station's nonvolatile EEPROM corresponding to the fields as follows.

All fields are 16-bit signed fixed point decimal integers.

<1>	X axis Gain value, hundredths used as multiplier.
<2>	Y axis Gain value, hundredths used as multiplier.
<3>	Z axis Gain value, hundredths used as multiplier.
<4>	X axis linear offset, hundredths of micro-Teslas.
<5>	Y axis linear offset, hundredths of micro-Teslas.
<6>	Z axis linear offset, hundredths of micro-Teslas.
<7>	X axis angular offset, tenths of degrees.
<8>	Pitch and Roll Damping, twentieths of a second.
<9>	Compass/RateGyro Damping, twentieths of a second.

Notes

Currently only Linear Offsets (X and Y) and Damping values are supported.
If in user calibration mode, the "Q" will be replaced by "INPROGRESS".
If a user calibration pass has been completed, the "Q" will be replaced by "PASS" or "FAIL".

$PAMTC,COMP,X

Summary

Terminate the user compass calibration mode.

Syntax

$PAMTC,COMP,X*hh<CR><LF>

Reply

$PAMTR,COMP,X,
<1>,<2>,<3>,<4>,<5>,<6>,<7>,<8>,<9>*hh<CR><LF>

Notes

Upon receiving $PAMTC,COMP,X user calibration mode will be terminated, if it had been previously entered by a $PAMTC,COMP,GO. The reply will always be issued.

If not in user calibration mode, the “X” will be replaced by “Q”.

$PAMTC,COMP,VERIFY

Summary

Verify the user compass calibration mode.

Syntax

$PAMTC,COMP,VERIFY*hh<CR><LF>

The verify user calibration sequence for the LB150 is as follows:

1. The weather station is installed on the vehicle. The unit under test is powered up. User calibration has been completed successfully.
2. The $PAMTC,COMP,VERIFY*hh<CR><LF> command is sent to the weather station's NMEA 0183 input channel to initiate user calibration mode.
3. During the verify user calibration process, the vehicle is rotated slowly (driven in a circle) and the sensor calculates the resulting score. Once the weather station has determined that enough data has been collected, it transmits the following sentence: $PAMTR,COMP,SCORE,XXX*hh<CR><LF>

Reply

The weather station will reply immediately with:
$PAMTR,COMP,INPROGRESS,
<1>,<2>,<3>,<4>,<5>,<6>,<7>,<8>,<9>*hh<CR><LF>

Where fields <1> through <9> contain the data from the weather station's nonvolatile EEPROM, as defined in the "Q", Query Command.

Upon successful completion the weather station will reply with:
$PAMTR,COMP,SCORE,XXX*hh<CR><LF>

Where XXX is a score from 0 – 255, meaning TBD.

Or, upon failure it will reply with:

$PAMTR,COMP,FAILx,
<1>,<2>,<3>,<4>,<5>,<6>,<7>,<8>,<9>*hh<CR><LF>

Where x indicates the type of failure, 1 = Timeout, 2 = Tilt Error, or 3 = Other Error.

NMEA 0183 RECEIVED SENTENCE

$PAMTC,DATUM

Summary

Define the local datum to which GPS position locations are referenced.

Syntax

One of the following forms:

```
$PAMTC,DATUM,SET,<3>,<4>*hh<CR><LF>
$PAMTC,DATUM,Q*hh<CR><LF>
```

Fields

<3>	Three character alphabetical code for local datum: W84 (WGS84) W72 (WGS72) S85 (SGS85) P90 (PE90) or IHO datum code from the International Hydrographic Organization Publication S-60 Appendices B and C.
<4>	One character subdivision datum code when available, as defined in IHO Publication S-60 Appendices B and C.

Notes

The $PAMTC,DATUM,SET,<3>,<4> command is used to establish the local datum used by the GPS receiver for calculating position. These values are stored in EEPROM memory within the unit. The default value for field <3> is W84 (WGS84). The default value for field <4> is a null field (no subdivision datum code).

Unlike other NMEA 0183 proprietary commands, if in the command $PAMTC,DATUM,SET,<3>,<4> field <4> is a null field, the value will be actually set to null (no subdivision datum code).

The $PAMTC,DATUM,Q command may be used to determine the current datum setting within the unit. Upon receiving this command, the unit will reply with $PAMTR,DATUM,<3>,<4>, where fields <3> and <4> are as described above.

The value established by this command will be used by the transmitted $GPDTM sentence.

KGS, OHI-A, OHI-B, OHI-C, OHI-D, OHI-M, SIR, P90, and S85 are not currently supported by the GPS Engine used in the LB150, and therefore are not available for use as Local Datum.

Important Note: Chart transformations based on IHO S60 parameters may result in significant positional errors when applied to chart data.

$PAMTC,EN

Summary

Enable or disable the periodic transmission of individual standard NMEA 0183 sentences, and specify their rate of transmission.

Syntax

One of the following forms:

```
$PAMTC,EN,<2>,<3>,<4>*hh<CR><LF>
$PAMTC,EN,S*hh<CR><LF>
$PAMTC,EN,L*hh<CR><LF>
$PAMTC,EN,LD*hh<CR><LF>
$PAMTC,EN,Q*hh<CR><LF>
```

Fields

<2> The identifier ALL, or one of the following sentence ID's:

DTM, GGA, GLL, GSA, GSV, HDG, HDT, MDA, MWD, MWVR, MWVT, RMC, ROT, VTG, VWR, VWT, XDRA, XDRB, ZDA

<3> If field <2> is the ALL identifier, then

0 = disable transmission of all sentences
1 = enable transmission of all sentences.

Otherwise,

0 = disable transmission of the specified sentence
1 = enable transmission of the specified sentence

<4> The amount of time between successive transmissions of the specified sentence, in tenths of a second. For example, if field <4> contains the value 5, this specifies an interval of 0.5 seconds between successive transmissions of the specified sentence.

If field <2> is the ALL identifier, then field <4> specifies the transmission interval for all sentences.

Notes

The factory default settings are as follows:

Sentence ID	Enabled by default?	Default Transmission Interval
DTM	–	10
GGA	✓	10
GLL	–	10
GSA	–	10
GSV	–	10
HDG	–	5
HDT	✓	5
MDA	✓	10
MWD	–	10
MWV (R)	✓	5
MWV (T)	–	10
RMC	–	10
VTG	✓	10
VWR	–	10
VWT	–	10
XDR (A)	✓	10
XDR (B)	✓	10
ZDA	✓	10

Note that the MWV sentence appears in two forms: relative (R) and theoretical (T). These two forms are enabled separately.

Also note that the XDR sentence appears in two forms: A and B. These two forms are also enabled separately.

If either of fields <3> or <4> is a null field, then that field will remain unchanged from its previous value.

The selections as to which sentences are enabled for transmission, and the rate at which each sentence is transmitted, are stored in nonvolatile EEPROM memory within the LB150 WeatherStation unit. On power up, these settings are copied from EEPROM into a working copy in RAM memory. It is the working copy in RAM that determines the behavior of the WeatherStation, with regard to the transmission of sentences.

Any changes to these settings using the $PAMTC,EN,<2>,<3>,<4> command only affect the working copy in RAM. When power is lost, the changes to the working copy in RAM will be lost.

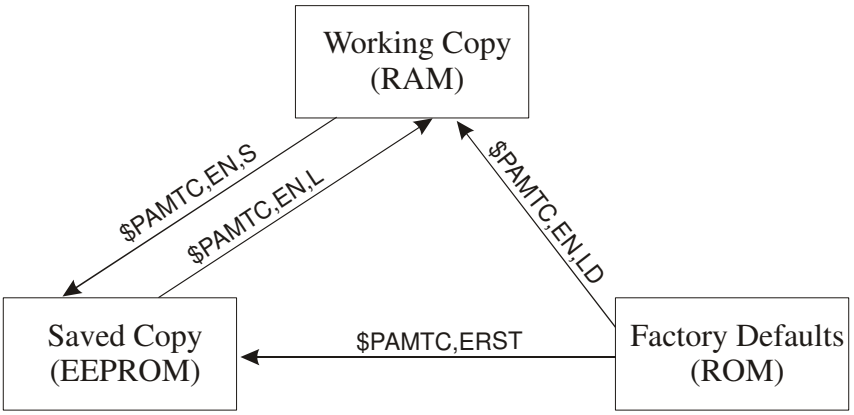
The **$PAMTC,EN,S** command causes the contents of the current working copy in RAM to be saved to EEPROM. The saved settings will then be restored to RAM each time power is applied to the unit.

The **$PAMTC,EN,L** command allows the settings to be reloaded from EEPROM to RAM without cycling power to the unit. This can be used to discard any changes made to the working copy in RAM, and restore the saved settings as though the unit had been turned off and then back on again.

The **$PAMTC,EN,LD** command loads the factory default settings from ROM memory into RAM memory.

Note that the $PAMTC,ERST command (see separate description) differs from the $PAMTC,EN,LD command in that $PAMTC,ERST will initialize *all* of user EEPROM memory to its factory default settings. This includes settings unrelated to the selection of transmitted sentences.

The above paragraphs are summarized in the below figure.



The **$PAMTC,EN,Q** command provides a query function to allow reading the current settings from the working copy in RAM. The reply to the $PAMTC,EN,Q command is a series of sentences with the following format:

```
$PAMTR,EN,<1>,<2>,<3>,<4>,<5>*hh<CR><LF>
```

where

<1> = Total number of $PAMTR,EN sentences in the reply
<2> = Sentence number
<3> = Sentence ID (GGA, GLL, GSA, GSV, HDG, MDA, MWD, MWVR, MWVT, RMC, VTG, VWR, VWT, or XDR)
<4> = 0 or 1 (0=disabled, 1=enabled)
<5> = Transmission interval (tenths of a second)

For example, a unit programmed with only the factory default settings would provide the following as a reply to the $PAMTC,EN,Q command:

```
$PAMTR,EN,19,1,DTM,1,10*17
$PAMTR,EN,19,2,GGA,1,10*17
$PAMTR,EN,19,3,GLL,0,10*13
$PAMTR,EN,19,4,GSA,0,10*00
$PAMTR,EN,19,5,GSV,0,10*10
$PAMTR,EN,19,6,HDG,0,5*2C
$PAMTR,EN,19,7,HDT,0,5*22
$PAMTR,EN,19,8,MDA,1,10*19
$PAMTR,EN,19,9,MWD,1,10*0E
$PAMTR,EN,19,10,MWVR,1,5*75
$PAMTR,EN,19,11,MWVT,1,10*46
$PAMTR,EN,19,12,RMC,0,10*3B
$PAMTR,EN,19,14,VTG,1,10*21
$PAMTR,EN,19,15,VWR,0,10*37
$PAMTR,EN,19,16,VWT,1,10*37
$PAMTR,EN,19,17,XDRA,0,10*6D
$PAMTR,EN,19,18,XDRB,0,5*59
$PAMTR,EN,19,19,ZDA,1,10*3E
```

Keep in mind when enabling sentences that the overall bandwidth of the interface should not be exceeded. At 4800 baud, only 480 characters can be transmitted in a one second period of time. If every one of the above sentences were enabled for transmission, their total number of characters could exceed 800. It is possible to use the $PAMTC,EN command to overspecify the amount of data transmitted, beyond the bandwidth capacity of the NMEA output channel. See section 2.1. for further information regarding bus bandwidth.

Examples

Example 1:

To disable all sentences for transmission, except transmit compass heading 5 times per second, and save the settings in EEPROM, send the following sequence of commands to the unit:

$PAMTC,EN,ALL,0
$PAMTC,EN,HDG,1,2
$PAMTC,EN,S

Example 2:

To reload the factory defaults for the $PAMTC,EN settings into EEPROM without affecting other EEPROM settings (such as attitude offsets set with the $PAMTC,ATTOFF command), send the following sequence of commands to the unit:

$PAMTC,EN,LD
$PAMTC,EN,S

Example 3:

To enable transmission of the XDR (A) sentence and set it to transmit at the slow rate of once every 10 seconds *for the current session only*, send the following command to the unit:

$PAMTC,EN,XDRA,1,100

Example 4:

To disable transmission of the MWV(T) sentence permanently:

$PAMTC,EN,MWVT,0
$PAMTC,EN,S

Example 5:

To enable transmission of all of the GPS-related sentences, and disable all others, for the current session only:

$PAMTC,EN,ALL,0
$PAMTC,EN,DTM,1
$PAMTC,EN,GGA,1
$PAMTC,EN,GLL,1
$PAMTC,EN,GSA,1
$PAMTC,EN,GSV,1
$PAMTC,EN,RMC,1
$PAMTC,EN,VTG,1
$PAMTC,EN,ZDA,1

NMEA 0183 RECEIVED SENTENCE

$PAMTC,ERST

Summary

Reset the user portion of nonvolatile EEPROM to its factory default state.

Syntax

`$PAMTC,ERST*hh<CR><LF>`

Notes

The following data items are saved in nonvolatile EEPROM within the LB150 WeatherStation. For each item, the default value, and the command used to change the value is shown.

Item	Default value	Changed via command
Azimuth offset	0.0°	$PAMTC,ATTOFF
Pitch offset	0.0°	$PAMTC,ATTOFF
Roll offset	0.0°	$PAMTC,ATTOFF
List of sentences enabled for transmission	See the description for the $PAMTC,EN command	$PAMTC,EN
Rates of transmission of sentences	See the description for the $PAMTC,EN command	$PAMTC,EN
Allow COG to be used instead of internal compass heading in true wind calculations	Disabled	$PAMTC,OPTION
GPS fix 2D, 3D, or Auto	Auto	$PAMTC,OPTION
Altitude settings	0,1,2	$PAMTC,ALT

Other items related to factory calibration of the sensor are also saved in EEPROM, but these items are not affected by the $PAMTC,ERST command.

NMEA 0183 RECEIVED SENTENCE

$PAMTC,HEATER

Summary

Control the internal heater within the weather station.

Syntax

One of the following forms:

`$PAMTC,HEATER,0*hh<CR><LF>`	Turn heater off (default state).
`$PAMTC,HEATER,A*hh<CR><LF>`	Control heater automatically.
`$PAMTC,HEATER,Q*hh<CR><LF>`	Query heater status, and start reporting subsequent changes in status
`$PAMTC,HEATER,X*hh<CR><LF>`	Stop reporting heater status change

Notes

The heater may be used in the weather station to prevent the formation of dew or ice on the aluminum plate in the wind channel. If the heater control is set to "A" (automatic control), then the weather station will automatically cycle the heater on and off over time to keep the plate temperature within appropriate limits based on the air temperature (and dew point temperature, if product has humidity sensor, PBxxx products do not, LBxxx products do).

If a `$PAMTC,HEATER,Q` (Query) command is received, then every time the heater status changes, the sensor will transmit the following message:

`$PAMTR,HEATER,<1>,<2>,<3>*hh<CR><LF>`

where

`<1>` = Heater mode (M = manual, A = automatic)

`<2>` = Heater state (0 = heater Off, 1 = heater On)

`<2>` = Heater control (V = Valid, if Factory enabled, else NULL)

Heater status change reporting may be disabled with the `$PAMTC,HEATER,X` command.

Note that when the heater is on, the air temperature sensor within the unit will be heated by the heater and will not provide an accurate indication of outside ambient air temperature.

This is a factory enabled option that is not present by default.

NMEA 0183 RECEIVED SENTENCE

$PAMTC,OPTION

Summary

Enable or disable certain WeatherStation features, or query their state.

Syntax

One of the following forms:

```
$PAMTC,OPTION,SET,<3>,<4>*hh<CR><LF>
$PAMTC,OPTION,Q,<3>*hh<CR><LF>
```

Fields

Option 1:

<3> 1 = Allow COG to be used instead of internal compass heading in true wind calculations

<4> 1 = Feature enabled
0 = Feature disabled (default)

Option 2:

<3> 2 = Set GPS fix mode

<4> 1 = 2D fix only
2 = 3D fix only
3 = Automatic selection of 2D or 3D mode (default)

Option 3:

<3> 3 = Set WAAS mode

<4> 0 = WAAS Disabled
1 = WAAS Enabled, but report fixes as GPS, Autonomous
2 = WAAS Enabled, report fixes as Differential

Option 4:

<3> 4 = Set WAAS Satellite

<4> 0 = Auto Mode (default)
120-138 = WAAS Satellite ID

Option 5:

<3> 5 = Enable Type 0 Messages

<4> 0 = Ignore Type 0 messages for 60 seconds
1-39 = Enable Type 0 messages as data
255 = Ignore Type 0 messages (default)

Notes

Option 1:

If the local magnetic inclination (dip) is severe, this can produce errors in the compass heading when the vehicle is not level. Since the compass heading is used in the calculations for true wind, this can also result in errors in the reported true wind speed and direction. (Apparent wind is not affected.) This option is not applicable to stationary instruments.

The WeatherStation can be instructed to use Course Over Ground (COG) provided by the internal GPS in place of the internal compass heading in the calculations for true wind. The command to enable this feature is $PAMTC,OPTION,SET,1,1. If this feature is enabled, then the COG will be used instead of internal compass heading *for calculation of true wind only* if the GPS has achieved a fix, and if the Speed Over Ground (SOG) is greater than 3 knots. If there is no GPS fix, or if the SOG is 3 knots or less, then the internal compass heading will be used.

Do be aware when using this feature that Heading and COG are not the same. Heading refers to the direction the front of the vehicle is *pointing*. COG refers to the direction the vehicle is *traveling*. While in an vehicle these values are likely to be nearly identical, in a boat they can differ because of the effects of wind and current on the vessel. The rationale for using COG instead of heading in the calculations for true wind is that the difference between COG and actual heading might be less than the error in the reported compass heading due to dip.

The setting is saved in nonvolatile EEPROM within the WeatherStation.

To disable this feature, use the command $PAMTC,OPTION,SET,1,0. When disabled, the COG will not be used in place of internal compass heading under any circumstances.

The WeatherStation may be queried to determine the state of this feature. If the command $PAMTC,OPTION,Q,1 is received, the unit will transmit the reply $PAMTR,OPTION,1,0 if the feature is disabled, or $PAMTR,OPTION,1,1 if enabled.

Option 2:

The GPS receiver in the LB150 can calculate a position fix when it has achieved a lock on at least three GPS satellites. If it has achieved a lock on four or more satellites, the unit may be able to calculate a *3D position fix*, meaning it can determine latitude, longitude, and altitude. But if it has achieved a lock on only three satellites, it may only be able to calculate a *2D position fix*, meaning it can determine latitude and longitude, but not altitude.

By default, the unit will automatically calculate a 3D position fix if it is able to, but will fall back to 2D position fixing if there are not enough satellites being tracked.

It is possible to restrict the operation of the GPS to only allow 3D position fixes by sending the unit the command $PAMTC,OPTION,SET,2,2. If this is done, then the unit will not calculate a position fix until it has achieved a lock on at least four satellites.

Note that sometimes the GPS may be tracking at least four satellites, but is still unable to calculate a position fix. This is because the positions of the satellites in the sky must be satisfactory in order to achieve good geometry in the fix calculation, as determined by the HDOP, VDOP, and PDOP values.

It is also possible to restrict the operation of the GPS to only allow 2D position fixes by sending the unit the command $PAMTC,OPTION,SET,2,1.

To re-enable the automatic selection of 2D versus 3D fix calculations, send the unit the command $PAMTC,OPTION,SET,2,3.

This setting is stored in EEPROM within the unit, and retrieved on power up.

The current setting may be queried by issuing the $PAMTC,OPTION,Q,2 command. The unit will respond with the sentence $PAMTR,OPTION,Q,2,<4>, where the value of <4> is 1, 2, or 3, corresponding to 2D, 3D, or Automatic mode, respectively.

When calculating a 2D position fix, the latitude/longitude values may have a relatively large error if the altitude of the GPS receiver is not set appropriately. This can be corrected by programming a fixed altitude offset into the unit. See the $PAMTC,ALT command on page 35.

Note that sometimes the GPS may be tracking at least four satellites, but is still unable to calculate a position fix. This is because the positions of the satellites in the sky must be satisfactory in order to achieve good geometry in the fix calculation, as determined by the HDOP, VDOP, and PDOP values.

Option 3:

The Wide Area Augmentation System (WAAS) uses a system of land based reference stations and geostationary satellites to augment the Global Positioning System (GPS) in order to provide additional accuracy, integrity, and availability. Several GPS Sentences are able to differentiate between WAAS (Differential) fixes and those fixes that do not use WAAS corrections.
The available WAAS modes are:

0 – Disable WAAS
1 – Enable WAAS, but report WAAS fixes as GPS (Autonomous, non-differential). This is provided for backward compatibility for systems that might not recognize WAAS (Differential) fixes.
2 – Enable WAAS, and report WAAS fixes as Differential.

The default mode is 2.
This setting is stored in EEPROM within the unit, and retrieved on power up.

Option 4:

This option can be used to direct the GPS to use a specific WAAS satellite. This value is NOT stored in EEPROM.

Option 5:

This option can be used to direct the GPS how to handle type 0 messages. This value is NOT stored in EEPROM.

NMEA 0183 RECEIVED SENTENCE

$PAMTC,**POST**

Summary

Perform the Power-On Self Test.

Syntax

`$PAMTC,POST*hh<CR><LF>`

The LB150 WeatherStation will reply with a sentence in the following form:

```
$PAMTR,POST,<1>,<2>,<3>,<4>,<5>,<6>,<7>,<8>,
<9>,<10>,<11>,<12>,<13>,<14>,<15>,<16>,<17>*hh<CR><LF>
```

Each of the fields <1> through <14> contains an integer value that represents the status of a simple test performed on a given submodule within the LB150 WeatherStation. For each field, a value of 0 (zero) indicates the unit passed the respective test; a nonzero value indicates a possible problem was discovered with the given submodule. Therefore, a properly operating unit (with all connected options) would reply with $PAMTR,POST,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,PB200. . A standard LB150 would output $PAMTR,POST,0,0,0,0,0,0,0,0,0,0,0,,,,0,PB200, where a Null field indicates sensor not present.

The fields and their corresponding submodules are listed below.

where

- <1> = Internal communication between microprocessors
- <2> = Format code
- <3> = Factory EEPROM
- <4> = User EEPROM
- <5> = Air temperature sensor
- <6> = Plate temperature sensor
- <7> = Standard relative humidity sensor
- <8> = Barometric pressure sensor
- <9> = Wind sensor
- <10> = Compass sensor
- <11> = GPS receiver
- <12> = Attitude sensor
- <13> = Rate gyro
- <14> = Optional Galltec relative humidity sensor
- <15> = Internal temperature Sensor
- <16> = Battery voltage Sensor

<17> = "PB200" string that indicates POST results are for the class of product described in this specification.

Notes

The various tests performed for the POST function are simple tests to determine if the hardware is minimally responding to software stimuli. The POST function should not be regarded as a comprehensive indicator that a given unit is healthy. In other words, it is possible that a defective unit might still pass the POST operation. However, the POST can be useful to identify certain types of problems with the WeatherStation.

Certain models of the WeatherStation may omit some features in the hardware. In this case, the corresponding fields in the POST sentence will be null (blank) fields.

The Power-On Self Test is performed automatically a few seconds after applying power to the unit.

NMEA 0183 RECEIVED SENTENCE

$PAMTC,**QPS**

Summary

Query part number and serial number information.

Syntax

`$PAMTC,QPS*hh<CR><LF>`

The LB150 WeatherStation will reply with a sentence in the following form:

`$PAMTR,QPS,<1>,<2>*hh<CR><LF>`

where

`<1>` = Part number string (up to 32 ASCII characters)
`<2>` = Serial number string (up to 32 ASCII characters)

Notes

The part number and serial number strings may not contain the following characters:

"$" (dollar sign)
"," (comma)
"*" (asterisk)
" " (space)

NMEA 0183 RECEIVED SENTENCE

$PAMTC,**QV**

Summary

Query version information.

Syntax

`$PAMTC,QV*hh<CR><LF>`

The LB150 WeatherStation will reply with a sentence in the following form:

```
$PAMTR,QV,<1>,<2>,<3>,<4>,<5>,
          <6>,<7>,<8>,<9>,<10>*hh<CR><LF>
```

where

- <1> = Null field
- <2> = Hardware version
- <3> = OEM option
- <4> = Null field
- <5> = Bootloader 1 firmware version
- <6> = Application 1 firmware version
- <7> = Bootloader 2 firmware version
- <8> = Application 2 firmware version
- <9> = GPS module version
- <10> = Compass module version

Notes

In the earlier model WeatherStation, the PB100, fields <1> and <4> in the reply to this command contained the 12-character part number and serial number fields, respectively. In the model LB150, the part number and serial number fields have been expanded to 32 characters to harmonize them with their NMEA 2000® equivalents. Because this would have caused this sentence to exceed the 82-character NMEA 0183 limit, these fields in the LB150 must be read using the $PAMTC,QPS command.

NMEA 0183 RECEIVED SENTENCE

$PAMTC,**RESET**

Summary

Reset the LB150 WeatherStation.

Syntax

`$PAMTC,RESET*hh<CR><LF>`

The WeatherStation will reset as though power had been removed and reapplied. All settings will revert to their power-on defaults.

NMEA 0183 RECEIVED SENTENCE

$PAMTC,**SIM**

Summary

Turn Simulate Mode On or Off.

Syntax

One of the following forms:

`$PAMTC,SIM,0*hh<CR><LF>`	Turn Simulate Mode Off (default state).
`$PAMTC,SIM,1*hh<CR><LF>`	Turn Simulate Mode On.
`$PAMTC,SIM,Q*hh<CR><LF>`	Query Simulate state.

The **$PAMTC,SIM,Q** command provides a query function to allow reading the current Simulate state. The reply to the $PAMTC,SIM,Q command is one of the following:

`$PAMTR,SIM,0*hh<CR><LF>`	Simulate Mode is Off
`$PAMTR,SIM,1*hh<CR><LF>`	Simulate Mode is On

Notes

The Simulate Mode is *not* stored in EEPROM. On power up, the Simulate Mode returns to the Off state.

NMEA 0183 RECEIVED SENTENCE

$PAMTX

Summary

Suspend and resume transmission of NMEA sentences.

Syntax

`$PAMTX,<1>*hh<CR><LF>`

Fields

`<1>`	0 = temporarily suspend transmission of all NMEA sentences. (default)
	1 = resume transmission

Notes

Upon receiving this sentence, the LB150 WeatherStation will suspend transmission of all future NMEA sentences after the currently transmitting sentence has completed.

If the $PAMTX command is received with no fields present (i.e. $PAMTX*50<CR><LF> or $PAMTX<CR><LF>, the default case shall prevail, i.e. transmission of sentences will be suspended.

Transmission of NMEA sentences will resume when one of the following has occurred:

- A `$PAMTX,1` command has been received.
- The power to the WeatherStation has been cycled.
- A `$PAMTC,RESET` command has been received.

3. Revision History

Revision 0.001
Date: 7/6/06
Description: Draft.

Revision 0.002
Date: 7/24/06
Description: Draft.

Revision 0.003
Date: 7/31/06
Description: Draft for Airmar internal review and comment.

Revision 0.004
Date: 9/16/06
Description: Draft.

Revision 0.005
Date: 10/12/06
Description: Draft.

Revision 0.006
Date: 3/7/07
Description: Draft.

Revision 0.007
Date: 3/28/07
Description: Draft.

Revision 0.008
Date: 11/26/07
Description: Draft. Added new proprietary PGNs 126720-49 and 126720-50 and $PAMTC,OPTIONs 4 and 5 for controlling WAAS Satellite selection and Enable GPS Type 0 Messages parameter selection. Added OPTION 3, enable WAAS. Added Device Temp/Voltage to POST results and PB200 to end of POST Sentence. Changed Device Temp/Voltage PGN to 65410. Made $PAMTC,ALT altitude units 0.1 meters. Added note about unsupported local datum codes.

Revision 0.009
Date: 03/04/08
Description: Draft. Added note to PGN 129029, that fields 16-18 are not present if field 15 is 0. Changed Heater PGN to Global. Changed Introduction to say 3d MEMS Accelerometer.

Revision 0.010
Date: 03/05/08
Description: Draft. Added Compass User Calibration Sentence and PGN details.

Revision 0.011
Date: 03/24/08
Description: Draft. Fixed version numbering and revised Compass User Calibration Sentence and PGN details. Added “damping” fields and resets. Compass User Cal INPROCESS changed to INPROGRESS.

Revision 0.012
Date: 04/10/08
Description: Draft. Made Heater a Factory enabled option. Updated Wind References in Meteorological Data PGN. User Compass Cal updates relating to Damping values. Converted to PB150 document. Made minor changes (added differential settings, clarified VWT)

Revision 0.013
Date: 08/07/08
Description: Draft. Added HDT and HDG as received sentences.