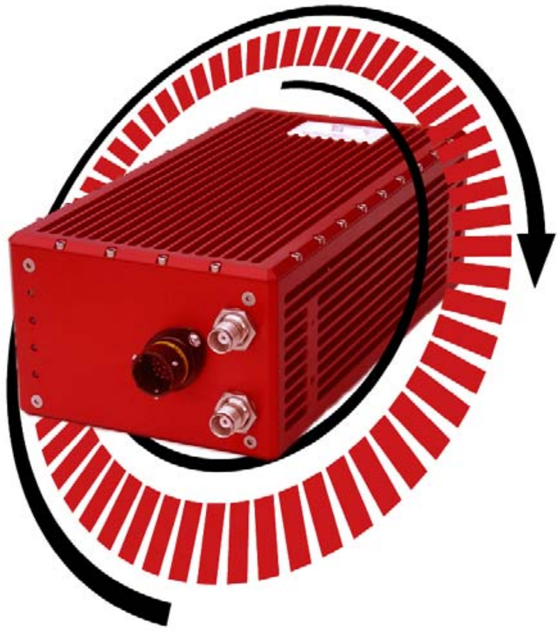
RT Inertial+

Inertial and GPS Measurement Systems



NMEA 0183 Description

Confidently. Accurately.

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Revision

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Introduction

NMEA is the National Marine Electronics Association. They make and control a standard for communicating measurements over RS232 called NMEA 0183. The standard includes measurements from GPS receivers and has been adopted by nearly every GPS receiver manufacturer. NMEA sell this standard and a full copy can be purchased from them.

The NMEA 0183 standard specifies the electrical connection (EIA-422) and the baud rate (4800 bits per second). However, in general these two parts of the specification are ignored. RS232 is typically used and, in order to transmit more data, higher baud rates are used.

NMEA uses ASCII (text) to encode its data, which makes the data readable without software. For example, if you open NMEA data in a text editor (notepad) then you can understand the file.

The data is encoded in sentences. Each sentence has a limit of 80 visible characters plus the carriage return and line feed (so 82 characters). This limit is often ignored by modern manufacturers and longer sentences are output.

Each sentence has a common structure. The first character is always a '$' character, followed by two characters that represent the type of equipment being used. For a GPS receiver this is "GP". Three characters are used to identify the type of sentence, i.e. these three characters give you information about the data in the rest of the sentence.

For example, if the first characters are:

$GPGGA,...

then the sentence is from a GPS receiver and contains GGA information. To decode this sentence the equipment needs to be able to understand the GGA sentence.

The fields that follow the sentence type are all separated by commas; they will be in ASCII text format and any numbers will use the '.' (full stop) as the decimal separator.

Technically, the OxTS inertial navigation systems could start with "IN" instead of "GP" to show that they are inertial navigation systems rather than GPS receivers. However, a lot of software will only decode the GGA sentence if it comes from a GPS receiver so they would not decode the string "$INGGA". OxTS does not output the system type as "IN", instead "GP" is always used.

A new standard is emerging which uses "GN" rather than "GP". This code indicates that other satellite positioning systems are being used rather than GPS. The term that includes all satellite systems is GNSS, whereas GPS is the subset run by the US government. A lot of equipment does not decode the “GN” type yet and so it is not used by OxTS.

Triggered NMEA sentences

The latest versions of the OxTS firmware support triggered NMEA sentences. By using one of the triggers in the RT, an NMEA sentence that relates to the time of the trigger can be output.

When it makes sense to interpolate the data in the sentence, the triggered sentence will have interpolated data. For example, it makes sense to interpolate time, position, velocity, orientation angles; it does not make sense to interpolate the number of satellites.

Sentence Descriptions

Table 1 lists the NMEA sentences that are supported by OxTS products.

Table 1. List of NMEA Sentences Output by the OxTS Products

Type	Name	See
GGA	Geographical Fix Information	Table 2
HDT	Heading True	Table 3
ZDA	Date and Time	Table 4
VTG	Velocity and Track over Ground	Table 5
GST	GPS Pseudorange Noise Statistics	Table 6
RMC	Recommended Minimum data for GPS	Table 7
PASHR	Heading, Pitch, Roll	Table 8

Using the default configuration files the NMEA sentences will be output in this order. The order is important because some of the sentences do not output time. It may be important to output a sentence with time in it before interpreting a sentence without time.

Checksum

The end of an NMEA sentence can have an optional checksum. All NMEA sentences output by the OxTS products include a checksum. The checksum is computed by XOR'ing all the characters from after the first '$' to before the checksum separator '*'.

In C this would be written as:

```
char sentence[] = "GPGGA,164917.00,,,,,1,08,0.9,,,,,,";
int i;
char checksum = '\0';

for( i = 0; i < strlen(sentence)-1; i++)
   checksum ^= sentence[i];
```

Now the variable `checksum` has the checksum in it. It can be compared to the values after the '*' in the received characters.

GGA, GPGGA – Geographical Fix Information

The GGA sentence contains position information and some status information about the position.

Because there are lots of fields in the GGA sentence, the sentence can exceed 80 characters under some conditions. This can cause some software to crash. OxTS has two NMEA modes: one that limits the output to 80 characters and another that exceeds the 80 character limit. In the mode where only 80 characters are output the undulation field will be blank.

The GGA sentence is in the following format the fields are described in Table 2.

$GPGGA,HHMMSS.SS,LLLL.LLLLLL,N,OOOOO.OOOOOO,E,Q,SS,D.D,A.AAA,M,G.GGG,M,DA,BID,*CS

Table 2. GGA Sentence Description

Field	Description
$GPGGA	Global Positioning System Fix Data
HHMMSS.SS	UTC time of day encoded as hours (24-hour format), minutes and seconds with 2 decimal places. Before time is valid this field will be blank. Note that the GPS time may be known but the UTC offset may not be known, in which case this field cannot be output. The UTC offset is not transmitted regularly by GPS and it can take a while before UTC time becomes valid.
LLLL.LLLLLL for example 5155.754164	Latitude. The first two digits are in degrees, the remaining digits are the minutes. In this example 51 degrees, 55.754164 minutes. 6 decimal places of minutes are always output, corresponding to less than 2mm resolution. The value is unsigned, see the 'N' field, below. This field is normally blank before the initialisation of the inertial navigation system. Using the "Output approximate values before initialisation" flag the field will output the antenna location from the GPS if the GPS has a valid fix but the inertial navigation system has not been initialised. After initialisation the longitude value output will always be from the inertial navigation system and not from the GPS receiver. This means it has a high update rate, low noise and is output continuously, regardless of the GPS quality.
N	Latitude is north (N) or south (S) of the equator.

Table 2. GGA Sentence Description, continued

Field	Description
OOOOO.OOOOOO for example 00115.045302	Longitude. The first three digits are in degrees, the remaining digits are the minutes. In this example 001 degrees, 15.045302 minutes. 6 decimal places of minutes are always output, corresponding to less than 2mm resolution. The value is unsigned; see the 'E' field, below. This field is normally blank before the initialisation of the inertial navigation system. Using the "Output approximate values before initialisation" flag, the field will output the antenna location from the GPS if the GPS has a valid fix but the inertial navigation system has not been initialised. After initialisation, the longitude value output will always be from the inertial navigation system and not from the GPS receiver. This means it has a high update rate, low noise and is output continuously regardless of the GPS quality.
E	Longitude is east (E) or west (W) of the Greenwich meridian.
Q	Fix Quality. This is the fix quality of the GPS and the inertial navigation system. 0 – Invalid, the latitude and longitude are not valid. Zero is also output before initialisation while approximate latitude and approximate longitude are output. 1 – Standard Positioning Service from GPS, no differential corrections. 2 – Differential GPS, i.e. corrections to the pseudorange but not matching any carrier phase between the base-station and the receiver. 3 – Precise Positioning Service, reserved for military applications and not supported by OxTS products. 4 – RTK Integer, the most precise positioning mode where the carrier phase ambiguity between the base-station is known. Typically 2cm accuracy or better. 5 – RTK Float, where the carrier-phase at the base-station is matched to the receiver but the ambiguity in the number of carrier phase cycles cannot be solved to an integer number. Typically 20cm accuracy. 6 – Dead Reckoning. The inertial navigation system can output this accurately even when GPS is not available. Software should be written so that it does interpret the position when the "Dead Reckoning" flag is set. Use the GPGST sentence to verify the accuracy of the measurements. Other values are not supported by the OxTS products.
SS	Number of satellites tracked by the GPS receiver.
D.D	Horizontal Dilution of Precision.
A.AAA	Altitude above the geoid, output to 3 decimal places.
M	Specifies that undulation is measured in metres.
G.GGG	In the "80 character compliant mode", this field is blank. In the extended mode this field represents the estimated height of the geoid. Usually this is computed using EGM96 but other techniques can be used.

Table 2. GGA Sentence Description, continued

Field	Description
M	In the "80 character compliant mode", this field is blank. In the extended mode this field specifies that the height of the geoid is in metres.
DA	Differential Age. The age of the differential corrections being used by the receiver in seconds. The field is limited to numbers between 0 and 99. For differential ages greater than 99 seconds the value will be saturated at 99.
BID	ID reference code for the base-station being used. For SBAS this is often the SBAS satellite number being used. The field is limited to numbers between 0 and 1023.
*CS	Checksum separator and checksum.

An example sentence, with UTC Time, in compliant (80 character) mode, without approximate position and before initialisation:

$GPGGA,164917.00,,,,,1,08,0.9,,,,,,*6A

An example sentence, after initialisation, in compliant (80 character) mode; note that the undulation is missing in this mode:

$GPGGA,164929.00,5155.755548,N,00115.066214,W,1,08,0.9,133.872,M,,,,*29

HDT, GPHDT – Heading True

The HDT sentence contains the true heading. This is the direction that the navigation system is *pointing* and does not relate to the velocity or direction of travel. For example, if the navigation system is travelling east, but pointing north then the heading angle will be north. The velocity or direction of travel is output by the VTG sentence.

The HDT sentence is in the following format and the fields are described in Table 3.

$GPHDT,HHH.HH,T*CS

Table 3. HDT Sentence Description

Field	Description
$GPHDT	Heading True
HHH.HH	True Heading of the navigation system, from 0 to 359.99 degrees, using 2 decimal places.
T	The character 'T' is output by the navigation system to represent that the heading is to true north. Grid north and magnetic north are not output.
*CS	Checksum separator and checksum.

Before initialisation the following (empty) sentence will be output:

$GPHDT,,*4F

After initialisation an example sentence is:

$GPHDT,356.92,T*0E

ZDA, GPZDA – Time and Date

The ZDA sentence contains the time and date. The time is always output as UTC time. There can be a delay between the navigation system being ready to run and UTC time being output. The navigation system uses GPS time, which is known first. There can be a delay before the offset between GPS time and UTC time is known.

The ZDA sentence is in the following format and the fields are described in Table 4.

$GPZDA,HHMMSS.SSS,DD,MM,YYYY,lh,lm*CS

Table 4. ZDA Sentence Description

Field	Description
$GPZDA	Date and Time.
HHMMSS.SSS	UTC Time encoded as HH (hours, 24 hour format), MM (minutes) and SS.SSS (seconds with three decimal places). This field will be blank until UTC time is known. GPS time may be known before UTC time is known.
DD	Day of the month (1 to 31).
MM	Month of the year (1 to 12).
YYYY	Year.
lh	Local Time Zone Hour Offset. This field is not output by the navigation system and is left blank.
lm	Local Time Zone Minute Offset. This field is not output by the navigation system and is left blank.
*CS	Checksum separator and checksum.

An example of the sentence once UTC Time is known is:

$GPZDA,164939.000,25,11,2008,,*5B

VTG, GPVTG – Velocity Track over Ground

The VTG sentence contains the velocity and “track over ground” angle. Track over ground is sometimes called “velocity vector angle” or “course over ground”. This is the direction that the navigation system is *moving* and does not relate to the direction that the navigation system is pointing. For example, if the navigation system is travelling east, but pointing north then the track over ground angle will be east. The heading angle, where the navigation system is pointing, is output by the HDT sentence.

When the velocity is exactly zero, the track over ground angle cannot be computed and a value of zero will be output.

The VTG sentence is in the following format and the fields are described in Table 5.

$GPVTG,TTT.TTT,T,ttt.ttt,M,NNN.NNN,N,KKK.KKK,K,Q*CS

Table 5. VTG Sentence Description

Field	Description
$GPVTG	Velocity and track over ground.
TTT.TTT	Track over ground angle of the navigation system, from 0 to 359.999 degrees, using 3 decimal places.
T	The character 'T' is output by the navigation system to represent that the track over ground is to true north. Grid north and magnetic north are not output.
ttt.ttt	This field is not output by the navigation system and is left blank (empty). It is normally the track over ground measured with magnetic north as the reference.
M	Indicates that the previous field, track over ground to magnetic north, is measured to magnetic north not true north.
NNN.NNN	Speed measured in knots. This is the speed at the navigation system, not the projected speed on to the ground. This field is output with 3 decimal places.
N	Indicates that the previous field is measured in knots.
KKK.KKK	Speed measured in km/h. This is the speed at the navigation system not the projected speed on to the ground. This field is output with 3 decimal places.
K	Indicates that the previous field is measured in km/h.
Q	GPS Status Indicator A – Autonomous, the Standard Positioning Service from GPS, no differential corrections, is being used. D – Differential, any differential corrections are being used. E – Estimated, No GPS is currently available. Note that some software may choose not to decode the sentence when 'E' is output but, using an inertial navigation system, the fields may be valid even when 'E' is output. N – Not Valid; this is not output by the navigation system. The field is blank instead. S – Simulator; this is not output by the navigation system. (blank) – GPS mode unknown
*CS	Checksum separator and checksum.

An example sentence before initialisation, but with GPS Position using the Standard Positioning Service, is:

$GPVTG,,T,,M,,N,,K,A*23

An example sentence after initialisation is:

$GPVTG,196.252,T,,M,0.370,N,0.686,K,A*0A

GST, GPGST – GPS Pseudorange Noise Statistics

The GST sentence contains estimates of the accuracy for the position measurements. These are straight from the Kalman filter's error states. In general the navigation system will claim a better accuracy than it really achieves; these measurements should be used as an indicator rather than for their true value. We have found that, because of the noise characteristics of the GPS, better results for velocity, roll, pitch and heading can be achieved by allowing the Kalman filter's position estimate to be better than the real measurement from GPS.

The GST sentence is in the following format and the fields are described in Table 6.

$GPGST,HHMMSS.SSS,PPP,MJR.RRR,MNR.RRR,AAA.A,L.LLL,O.OOO,H.HHH* CS

Table 6. GST Sentence Description

Field	Description
$GPGST	GPS Pseudorange Noise Statistics
HHMMSS.SSS	UTC Time encoded as HH (hours, 24 hour format), MM (minutes) and SS.SSS (seconds with three decimal places). This field will be blank until UTC time is known. GPS time may be known before UTC time is known.
PPP	RMS of the pseudorange measurements. This field does not have any significance once the data has been processed by the navigation system and is always blank.
MJR.RRR	Semi-major axis of the position co-variance expressed as a standard deviation, measured in metres and with 3 decimal places. This field will be blank before the navigation system has initialised.
MNR.RRR	Semi-minor axis of the position co-variance expressed as a standard deviation, measured in metres and with 3 decimal places. This field will be blank before the navigation system has initialised.
AAA.A	Heading angle of the semi-major axis from true north, measured in degrees and with 1 decimal place. This field will be blank before the navigation system has initialised.
L.LLL	Standard deviation of the latitude measurement, measured in metres and with 3 decimal places. This field will be blank before the navigation system has initialised.
O.OOO	Standard deviation of the longitude measurement, measured in metres and with 3 decimal places. This field will be blank before the navigation system has initialised.
H.HHH	Standard deviation of the altitude measurement, measured in metres and with 3 decimal places. This field will be blank before the navigation system has initialised.
*CS	Checksum separator and checksum

An example of the GST sentence, with UTC Time known but before initialisation is:

$GPGST,164917.000,,,,,,,*45

An example of the GPS sentence after initialisation is:

$GPGST,164937.000,,1.184,1.173,140.9,1.180,1.177,2.384*46

RMC, GPRMC – Recommended Minimum for GPS

The RMC sentence is the most common sentence output by GPS devices because it contains a lot of measurements in one sentence. The sentence includes time, position and velocity information.

The RMC sentence is in the following format and the fields are described in Table 7.

$GPRMC,HHMMSS.SS,Q,S.SSS,TTT.TTT,DDMMYY,MAG,MAG2,Q2*CS

Table 7. RMC Sentence Description

Field	Description
$GPRMC	Recommended minimum for GPS
HHMMSS.SS	UTC Time encoded as HH (hours, 24 hour format), MM (minutes) and SS.SS (seconds with 2 decimal places). This field will be blank until UTC time is known. GPS time may be known before UTC time is known.
Q	Position Status. A – Valid Position; the position will always be valid once the navigation system has initialised V – Invalid Position; output before initialisation

Table 7. RMC Sentence Description, continued

Field	Description
LLLL.LLLLLL for example 5155.754164	Latitude. The first two digits are in degrees, the remaining digits are the minutes. In this example 51 degrees, 55.754164 minutes. 6 decimal places of minutes are always output, corresponding to less than 2mm resolution. The value is unsigned, see the 'N' field, below. This field is normally blank before the initialisation of the inertial navigation system. Using the "Output approximate values before initialisation" flag, the field will output the antenna location from the GPS if the GPS has a valid fix but the inertial navigation system has not been initialised. After initialisation the longitude value output will always be from the inertial navigation system and not from the GPS receiver. This means it has a high update rate, low noise and is output continuously regardless of the GPS quality.
N	Latitude is north (N) or south (S) of the equator.
OOOOO.OOOOOO for example 00115.045302	Longitude. The first three digits are in degrees, the remaining digits are the minutes. In this example 001 degrees, 15.045302 minutes. 6 decimal places of minutes are always output, corresponding to less than 2mm resolution. The value is unsigned, see the 'E' field, below. This field is normally blank before the initialisation of the inertial navigation system. Using the "Output approximate values before initialisation" flag the field will output the antenna location from the GPS if the GPS has a valid fix but the inertial navigation system has not been initialised. After initialisation the longitude value output will always be from the inertial navigation system and not from the GPS receiver. This means it has a high update rate, low noise and is output continuously regardless of the GPS quality.
E	Longitude is east (E) or west (W) of the Greenwich meridian.
S.SSS	Speed measured in knots. This is the speed at the navigation system, not the speed projected on to the ground. This field is output with 3 decimal places.
TTT.TTT	Track over ground angle of the navigation system, from 0 to 359.999 degrees, using 3 decimal places.
DDMMYY	DD (Day of the month, 1 to 31). MM (Month of the year, 1 to 12), YY (Year, after truncating the century, 2 digits only).
MAG	Magnetic variation, degrees. This is not output by the navigation system and the field is blank.
MAG2	Magnetic variation direction (E – east, W – west). This is not output by the navigation system and the field is blank,

Table 7. RMC Sentence Description, continued

Field	Description
Q2	GPS Status Indicator A – Autonomous, the Standard Positioning Service from GPS, no differential corrections, is being used. D – Differential, any differential corrections are being used. E – Estimated, no GPS is currently available. Note that some software may choose not to decode the sentence when 'E' is output but, using an inertial navigation system, the fields may be valid even when 'E' is output. N – Not Valid; this is not output by the navigation system. The field is blank instead. S – Simulator; this is not output by the navigation system. (blank) – GPS mode unknown
*CS	Checksum separator and checksum

An example RMC sentence, with UTC Time known, approximate position not output and before initialisation is:

$GPRMC,164917.00,V,,,,,,,251108,,,A*71

An example RMC sentence after initialisation is:

$GPRMC,164936.00,A,5155.755550,N,00115.066091,W,0.343,162.813,251108,,,A*49

PASHR – Proprietary Heading, Pitch, Roll, Heave measurements

The PASHR sentence contains UTC time, heading, pitch, roll and heave measurements. Accuracy data for the measurements is also included.

The PASHR sentence is in the following format and the fields are described in Table 8.

$PASHR,HHMMSS.SSS,HHH.HH,T,RRR.RR,PPP.PP,aaa.aa,r.rrr,p.ppp,h.hhh,Q1,Q2*CS

Table 8. PASHR Sentence Description

Field	Description
$PASHR	Proprietary Heading, Roll, Pitch and Heave
HHMMSS.SSS	UTC Time encoded as HH (hours, 24 hour format), MM (minutes) and SS.SSS (seconds with 3 decimal places). This field will be blank until UTC time is known. GPS time may be known before UTC time is known.
HHH.HH	True Heading of the navigation system, from 0 to 359.99 degrees, using 2 decimal places.
T	The character 'T' is output by the navigation system to represent that the heading is to true north. Grid north and magnetic north are not output.
RRR.RR	Roll of the navigation system, measured in degrees, with leading sign, leading 0's where needed and 2 decimal places. Positive values mean that the left side is up.
PPP.PP	Pitch of the navigation system, measured in degrees, with leading sign, leading 0's where needed and 2 decimal places. Positive values mean that the front is up.
aaa.aa	Heave of the navigation system, measured in metres, with leading sign, leading 0's where needed and 2 decimal places. This is not output by the navigation system.
r.rrr	Roll accuracy in degrees and with 3 decimal places.
p.ppp	Pitch accuracy in degrees and with 3 decimal places.
h.hhh	Heading accuracy in degrees and with 3 decimal places.
Q1	GPS Position mode. 0 – No GPS position fix 1 – All GPS position fixes apart from "2" 2 – RTK Integer position fix
Q2	IMU Status 0 – IMU is OK 1 – IMU error
*CS	Checksum separator and checksum

An example of the PASHR sentence, with UTC Time but before initialisation is:

$PASHR,164917.000,,,,,+00.00,,,,1,0*62

An example of the PASHR sentence after initialisation is:

$PASHR,164937.000,355.98,T,-00.54,+00.54,-00.24,0.672,0.690,7.130,1,0*09

Revision History

Table 9. Revision History

Revision	Comments
090206	Initial version